THE

JOURNAL OF GEOLOGY

OCTOBER–NOVEMBER, 1908

STRUCTURAL GEOLOGY OF THE MIDDLE YANG-TZĬ-KIANG GORGES

E. C. ABENDANON

During the first half of the year 1904 I made an exploration trip in the province Ssĭ-ch'uan of West China, which I reached by going up the Middle Yang-tzĭ-kiang from I-ch'ang to Chung-king. The results of this journey are published in the *Revue Universelle des Mines* (1906), of which a separate edition[1] also appeared. The reason why I now return to this subject is to compare my results with those obtained by Messrs. Bailey Willis and Eliot Blackwelder, who—and this is a curious coincidence—reached I-ch'ang on the same day (June 9, 1904) as I did, after our travels in China. To my regret this coincidence did not lead to our meeting, either at I-ch'ang or on board the steamer to Hankow. Their researches and personal views were published in the splendid work, *Research in China*, under the auspices of the Carnegie Institution of Washington, in April, 1907.

In this description of the structural geology of the Middle Yang-tzĭ-kiang[2] I shall go much more into details than in my publication about the Red Basin. On the other hand, I shall only cursorily describe the encountered formations and not enter into the peculiarities of the separate strata. In contrast to my former description I shall not this time mention my observations in an upriver direction, but in a downstream one, this manner having the advantage, as we shall

[1] *Géologie du Bassin Rouge de la province Se-Tchouan en Chine.*

[2] The accompanying map has been put together, as far as topography is concerned, from those of Arthur Kniep and R. H. Sargent.

presently see, that the windings of the river can be explained in detail from the geological structure of the country.

From K'ui-chóu-fu to I-ch'ang the Yang-tzī flows, for a distance of 135 km. through the ranges of mountains bordering the Red Basin of Ssī-ch'uan. Formerly I have already observed that the anticlines, which in the Red Basin strike almost NNE–SSW, are bent round in the north and east toward the NE, ENE, and E. To explain this, I assumed that the Red Basin had been forcibly pressed up against the old mountain ranges of Kuen-lun and Tsin-ling-shan trending in almost equatorial direction. The trends in these border ranges of the Red Basin do not therefore conform to the normal in the basin itself.

From K'ui-chóu-fu to I-ch'ang the Yang-tzī-kiang cuts the following formations:

1. A granitic formation intersected by numerous dykes of granite, diorite,[1] and melaphyre, all of them striking almost N–S.

2. Metamorphic schist, consisting of hornblende, chlorite, and mica schists, alternating with layers of nearly pure quartz.

3. Purplish-brown limestone with fossils, among which is a coiled nautilus, which, according to Professor Frech, of Breslau, marks the Lower Silurian. The most striking are, however, the numerous and very large casts of Orthoceratites. This is, I believe, the Cambro-Ordovician Ki-sin-ling limestone of Blackwelder and Willis.

4. Green shales of about 900 m. thickness; this the Middle Paleozoic Sin-t'an shale of the afore-named gentlemen.

5. The gorges-limestone formation, 1,600 m. thick, called by the two other explorers Wu-shan limestone.

As, according to my researches, not only a part of the Wu-shan gorge but all the gorges are built up of this formation, I consider the name gorges-limestone better than Wu-shan limestone. This formation is considered as belonging to the "Upper Carboniferous" by said gentlemen.

What Blackwelder comprises in the K'ui-chóu series, has been divided by me as follows:

6. The reddish-brown sandstone and argillite formation, 300 m. thick.

[1] Under these names are comprised various kinds of aplitic and lamprophyric "Ganggesteine" of granito-dioritic character.

7. The slaty limestone formation, 300 to 400 m.

8. The sandstone formation, with layers of coal, whose flora belongs to the Rhetian, 600 m.

9. A formation, 1,800 to 2,500 m., of alternating strata of sandstone and argillite, the former of which are generally of eolian origin. This has been named by me the K'ui-chóu formation.

Between 8 and 9 there is, in the middle of the Red Basin, a series of marls, 50 m. thick, but this is lacking in the bordering part.

The formations 7 and 8 I believe I may count as belonging to the Permian or to the Lower Triassic, and to the Upper Triassic.

The stratum between 8 and 9 seems to belong to the chalk formation, so that the K'ui-chóu formation, in which I did not find any organic remains, may be considered as belonging to the chalk formation, and, taking into account the thickness of the formation, it might be assumed that the deposit continued into the Tertiary Period.

The folds of the Red Basin of Ssī-ch'uan are of later date than the K'ui-chóu formation. As latest formation must be named the following:

10. A conglomerate bank, which I have encountered in several parts along the Yang-tzī-kiang. The bowlders and pebbles in this conglomerate generally are of eruptive origin whereas the cement consists of a calcareous siliceous tufa. This must therefore be the latest formation, whose origin dates after the folding of the Red Basin.

We will now describe the structural geology of the Middle Yang-tzī-kiang gorges going downstream from K'ui-chóu to I-ch'ang. Coming from the synclinal area, west of K'ui-chóu-fu, the Yang-tzï for the first time encounters the high gorges-limestone mountain ranges, to the east of that place. On the left bank the river tries to penetrate the softer upper strata so that a creek is formed there. But as the softer layers, which formerly spread out like a mantle over the anticlinal gorges-limestone mountain range, and nowadays have been washed away from the crests of this range, still, as a whole, form a kind of dam, the Yang-tzï is forced to make a bend toward the first of the great gorges: the Fong-hiang-hia or gorge of K'ui-chóu-fu. This gorge being a deep incision of the big river through the mountain range east of K'ui-chóu-fu, clearly shows its structure.

The gorges-limestone strata strike about ENE–WSW and dip

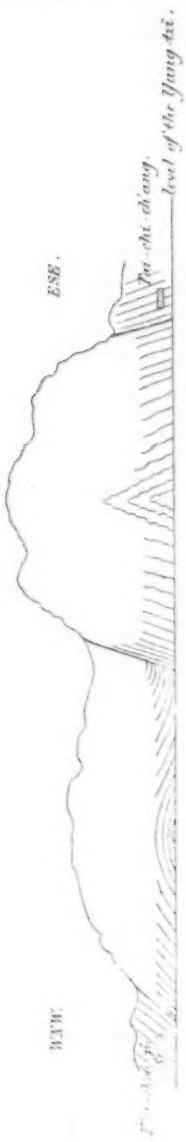


Fig. 1

40° WNW. The river narrows considerably and the banks at once rise to double the height of what they were outside the gorge. Soon the dip decreases to 25°, and in the deeper levels of the formation to 7° or 8°. Now soon follows the anticlinal flattening of the layers, and after a pretty long distance with the strata in horizontal position the southerly inclined limb also makes an angle of 7° to 8°. This is a broad and low fold. Suddenly the strata, with a faint southerly dip, bend round sharply and get a northerly dip, and now the layers rise to the south under an angle of 70°. This time the anticlinal folding follows much sharper, and the southern limb dips 75° south. In both limbs, and in the crest of the anticline itself the layers are not straight, but waved, and show many secondary plications. All this points to a strong compression and forcing outward of this anticline.

The structure of this first limestone mountain range as it appears in the gorge of K'ui-chóu-fu, therefore, is that of two folds strongly pressed together, each of which takes up just one-half of the length of the gorge on the river level (see Fig. 1).

As soon as the river, a little way above Tai-chi-ch'ang, issues from the gorge, it re-obtains a double width in the syncline area of Wu-shan. To the north and to the south the river is inclosed by the lofty gorges-limestone mountains, and the next gorge is already perceptible in the range south of the Yang-tzĭ. In this syncline nothing is left of the later formations but the reddish-brown and the slaty limestone formations,

with a slight relic of the sandstone formation. It is a strongly compressed syncline, by reason of which compression a commencement of dynamo-metamorphosis is observable, especially the reddish-brown formation, recognizable by the far greater hardness of its sandstone layers, and, besides that, by their becoming slaty on account of the greater amount of mica they contain.

In the following description of the different strata and their position in the synclinal area of Wu-shan, I must neglect details and shall merely describe the structure in general features.

The Yang-tzï, which in the K'ui-chóu-fu gorge flowed almost vertically to the trend of the strata, downstream Tai-chi, transects the reddish-brown and the slaty limestone formations which also dip SSE, and, after a wedge-like compressed syncline, it strikes against the 25° NNW-dipping limb of the anticline south of the river. This causes the river near K'ui-ché-pan to bend from its ESE course into a NE direction. In this part the layers are much disturbed, and a relic of the sandstone formation is found among the slaty limestones. Near Tan-tia-wan the river has again gone too far north and has abutted, in steeply SSE-dipping layers, against the southern limb of the northern anticline. The river is now again forced to bend, and flows in a WNW direction through the strata of the slaty limestone formation, which, at first dipping faintly SSE, soon becomes almost horizontal, and then again dips 50° NNW; and lastly the river forces its way into the reddish-brown formation, which also dips precipitously north. Near Wu-shan the river has thus, for the second time after Tai-chi, entered the northern limb of the southern anticline, which it has again transected in a gorge just below Wu-shan.

Before describing this gorge, being another magnificent section through a high mountain range, I will just discuss the profile of the Ta-ning-ho, a tributary river, which flows into the Yang-tzï near Wu-shan. Going in a NNW and N direction from Wu-shan, along very hilly territory, in whose narrow synclinal valleys I only found relics of the reddish-brown and of the slaty limestone formations, I reached the place Ta-ch'ang or Kiu-shï-li-p'u on the Ta-ning-ho. This swift narrow mountain stream I followed to its confluence with the Yang-tzï. Owing to the imposing gorges through which we passed, and to the remarkable skill and proficiency in navigation with which

the skippers of the river craft guided their boats over rapids and along an almost rectangular bend in the river, where the current set straight upon the steep cliffs, this was certainly one of the finest and most stirring of my water trips in China. The rapids are generally formed in synclinal territory by bars of bowlders; here the river is broad and its banks are generally lower. Only once there was a fall of a few feet in the bed of the river itself. In the limestone gorges the river is much narrower and confined between high steep cliffs.

My observations there coincide pretty well with those of Willis and Blackwelder. On pp. 277, 278 of their work[1] they say: "Along the Ta-ning-ho the red series seems to be devoid of coal which may lie higher in the system than any strata remaining in those synclines." As I have already observed before, there only remain in these synclines the strata that lie far below the sandstone formation with its layers of coal.

Ta-ch'ang is situated in a rather wide synclinal area. If we go down the Ta-ning-ho, a very winding river, along whose course many pebble banks form small rapids, we reach after a sharp bend the first gorge, the Lao-men-hia.[2] Here again the gorges-limestone strata is folded up in an anticline of which the northern limb dips steeply and the southern limb but faintly. It took us a little more than an hour to pass this gorge. During twenty minutes we next float down through a synclinal, more open area, with a dangerous rapid, which leaves but a narrow passage-way between banks of pebbles; and then we reach the next gorge, which exposes two lower folds pressed together. The southern limb of the second of these folds dips 20°–30° SSE. The gorge, called "Lung-chin-hu-cho-hia," or "gorge of the dragon and tiger," is passed in fifty minutes. Sin-t'an-hia[3] is situated at the lower end of the gorge, which again opens on a second synclinal area, in which the river makes almost a loop. Here again was a very difficult rapid, at least when the water is at the height encountered by me. The next and fourth anticline is less broad, and then, after a short synclinal area, there again follows a gorges-limestone anticline, in which the now very swiftly flowing Ta-ning-ho has excavated a narrow gorge. To reach this gorge we had to pass a very

[1] *Research in China.*

[2] Old Gate Gorge.

[3] Literally, New Rapid Gorge.

difficult rapid, just at a place where the river made a rectangular turn. This too was negotiated with remarkable skill by the two steersmen standing, the one fore and the other aft; these two men and myself being the only members of the party to remain on board the sloop, the others preferring to walk along the river banks.

These last two anticlines must be considered as the easterly prolongation of those of the gorge of K'ui-chóu-fu. We see that these two anticlines, having diverged east of K'ui-chóu-fu, have got limbs of almost equal dip, and have therefore become lower from west to east, especially the southern one.

It takes nearly two hours to go down stream from Sin-t'an-hia to the lower end of the last gorge and twenty minutes more through the synclinal area to Wu-shan.

From K'ui-shī-li-p'u to Wu-shan five anticlines with an almost equatorial direction, which lie close together, are thus transected by the Ta-ning-ho. Just below Wu-shan the Yang-tzī makes a bend like the one below K'ui-chóu-fu, and leaves the steeply NNW-dipping reddish-brown formation, to enter the 80° NNW-dipping gorges-limestone formation. In this second of the grand gorges of the middle Yang-tzī the river flows at first almost in the trend of the layers, only gradually reaching deeper levels. This already points to the sinking of the anticline, to which this limb belongs, viz., in an easterly direction. Just upstream before the hamlet Klao-che, the river, which in this part of the gorge has but slightly narrowed, enters the underlying formation, the olive-green Sin-t'an shale, of which the upper part is brownish red. We now perceive on the left bank a very fine dome[1] in the gorges-limestone formation, below which the observed Sin-t'an shale are situated (see Fig. 2). We also observed that from west to east the Sin-t'an shale remains much lower, which also points to a sinking of the anticline toward the east. After having for a short distance transected the southern limb of this anticline in the gorges-limestone, below Wen-che-chi we find very markedly plicated

[1] Willis and Blackwelder, *op. cit.*, Vol. I, p. 287: "Northwest of the grand arch of the Wu-shan limestone, probably one of the most superb exposures of a fold in the world, the K'ui-chóu red beds occur in the syncline, and the Yang-tzī valley is developed in them for some miles westward." From the above it is clear that in this case under the K'ui-chóu red beds must be understood the reddish-brown and the slaty limestone formation, but not the proper K'ui-chóu series.

layers in the same formation, which eventually dip 65° NW near Sui-che-t'an. The Yang-tzĭ is bent round to the SSE and cuts almost vertically the next anticline, the upper strata of the northern limb of which are, as just mentioned, strongly compressed. The NW dip of the layers at first increases to 80° and then diminishes to 25°. And then the anticlinal arch in both of the limestone walls becomes beautifully visible. This very fine section, in the middle of which the two limbs of the anticline, both dipping 25°–30°, are most clearly exposed, stretches over almost the whole length of the SSE-directed course, in which the narrow Yang-tzĭ flows below Wen-che-chi. In the last part of the SE limb the layers dip 70° south.

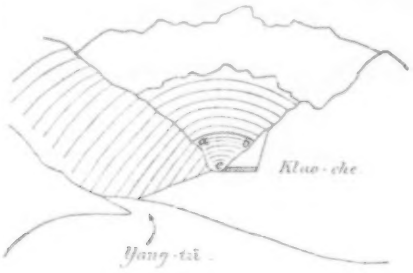


FIG. 2

Near Ts'ing-shĭ-tung the Yang-tzĭ turns sharply to the east, and flows through the eastern continuation of a valley, formed by a wedge-shaped syncline (like that reproduced in Fig. 3). Inside the valley looking west, we could see a series of south-dipping layers of the reddish-brown formation, but soon below Ts'ing-shĭ-tung the river banks are formed of 50° to 55° north-dipping layers of gorges-limestone, which shows that the river, emerging from the wedge-formed connection of the two anticlinal limbs, has pierced into the northern limb of a southern anticline, which, in this part, trends nearly EW. From Ts'ing-shĭ-tung to Fu-li-chi, the Yang-tzĭ remains in the upper part of the gorges-limestone formation, which causes

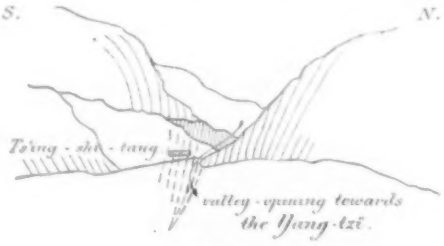


FIG. 3

the river to become broader and the banks, especially the left bank, less high. The right bank rises much higher, according to the dip of the layers toward the north. Before Pei-chi the gorges-limestone limb bends slightly toward the SE, visible by the NE dip of the layers. After a short transversal fault, the EW trend of the anticline reappears. Before a cleft in the river bank near Leng-sui-chi, where the layers show many plications, a bar of stones has been formed, and in the gorge itself there is a small rapid, a thing which is very rare in the gorges. A little farther on, we see in front of a cleft in the left bank a bar, formed by many reddish-brown and gray pebbles, which reveals the existence, to the north of the river, of a synclinal area of the reddish-brown formation. In fact, I found to the north of Fu-li-chi, the reddish-brown, and also part of the slaty limestone formation, with very slaty layers, caused by the strong compression of the narrow syncline. These show, especially in the slaty limestone, all the colors ranging from reddish-brown, orange, yellow, and olive green to grayish-blue. Just before Fu-li-chi there again appears in the mountains to the south of the Yang-tzĭ a fine dome, standing almost vertically on the river, which thus points to the existence of a third anticline (see Fig. 4). Below Fu-li-chi, till Nan-mu-yüan, the river again penetrates the deeper levels of the gorges-limestone formation. The secondary plications accompanied by small faults, are continued in the layers, which have a general EW trend and dip 60° N. Below Yang-chi-p'ong the river, which was flowing ESE and E, turns to the NE. For this fact we soon find the explication in the NW-dipping layers, which therefore point to a turning of the anticlinal axis from an EW to a NSW–NE direction. In this latter portion of the gorge the layers show many small secondary folds and faults, while to the south of the Yang-tzĭ, in the higher mountains, once more an indication of the anticline is given in the layers that are bent round to a horizontal position. At last, near Kuan-tu-k'ou, we emerge from

FIG. 4

the 45 km. long Wu-shan gorge, through layers, dipping rather steeply N, of the upper levels of the gorges-limestone which show a turning of the anticlinal axis toward W–E.

To recapitulate we see that as far as the Wu-shan gorge exposes the structure of the mountain range south and east of Wu-shan, this range appears to be formed by three anticlines, closely pressed together. Of these the anticline farthest upstream rises highest, for in that we see the green slaty formation underlying the gorges-limestone formation. (Fig. 5 gives a sketch of my conception of the geological structure of this gorge.) The Yang-tzī has cut its course quite through the northern two anticlines, and then through part of the northern limb of the southernmost one.

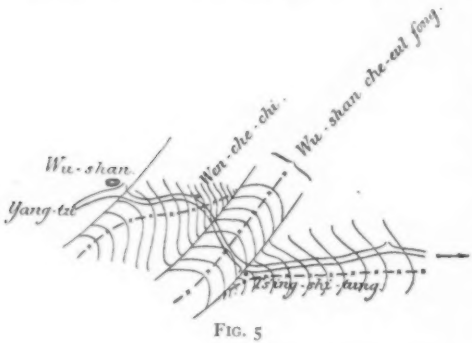


FIG. 5

From the above it will appear that my observations, which were taken while going upstream, at the rate of 25 km. a day, differ in many particulars from those of Willis, which were taken during the so much swifter course downstream.

The principal difference is, that Willis considers a great part of the Wu-shan gorge to be formed of Ki-sin-ling limestone, while I maintain that nothing but the gorges-limestone, Willis' Wu-shan limestone, appears in that gorge.

Willis writes: "Below Nan-mu-yüan the base of the Wu-shan limestone is marked by the occurrence of black cherts and it may be assumed that the Sin-t'an (middle Paleozoic) shale occurs in its proper place below the limestone, but we did not see it."[1]

From what I have written above, it appears, that the thick Sin-t'an shale formation was not observed by me either in that place, although it would have been almost an impossibility to overlook it (had it been there) going, as I did, so slowly upstream. Besides, in

[1] *Op. cit.*, Vol. I, Part 1, pp. 286, 287.

connection with the rest of my researches, it could not be expected to occur there. Willis continues:

> Between Nan-mu-yüan and Wu-shan-hien the Yang-tzï flows across a sequence of smaller and larger folds, chiefly of the Ki-sin-ling limestone, but, at the head of the gorge, consisting only of the Wu-shan limestone. The sequence will best be understood by reference to the section [see his Fig. 61], which was sketched, as we floated past the magnificent cliffs in which it was exposed. As we could not measure distances, the distribution along the river was noted and has since been adjusted to "Chevalier's map of the Yang-tzï." Two anticlines and a syncline bring the top of the Ki-sin-ling limestone high above the stream, above and below Nan-mu-yüan. For several miles below Ts'ing-shi-tung the course is in the axis of a carinate syncline, a position determined by the Sin-t'an shale, although the canyon is now sunk below that formation in the Ki-sin-ling limestone. The thin beds of the latter dip very steeply, but above them, in a nearly flat position, the Wu-shan forms the upper cliffs. From half a mile above Ts'ing-shï-tung the synclinal valley extends westward but it is occupied only by a small tributary. The lower part of the Wu-shan gorge is cut across a great anticline of the Ki-sin-ling, the arch extending up to the mountain tops 3,000 feet or more above the river. The inner part of the anticline in the thin-bedded strata, near the base of the formation, is therefore exposed along the water level, and is seen to be characterized by many sharp folds and possibly by minor overthrusts. The details could not be followed as we passed, but the major structure was clear. Finally, toward the west, the dip is continuous on the northwestern limb of the arch, and the Sin-t'an shale comes in above the limestone.[1] The shale is overlaid by the Wu-shan limestone with characteristic black chert of the lowest beds. There is a repetition of the shale and limestone with black chert, occasioned by a slight overthrust at this horizon of adjustment, and then follows the mass of the Wu-shan limestone forming the upper part of the Wu-shan gorge.

We see that this description differs very materially from my researches. In confirmation of my own views I must remark that it is far more difficult to take careful observations while going rapidly downstream than during the slow course upriver. I myself experienced this on my return journey.

If we now continue the course of the Yang-tzï, below K'uan-tu-k'ou, it will appear that an ever-widening synclinal area is occasioned between two anticlines, viz., the middle anticline of the Wu-shan gorge with its NE–SW trend, which in the NE is probably bent ENE–WSW, and the almost true equatorial trend of the southernmost of

[1] This was not observed by me.

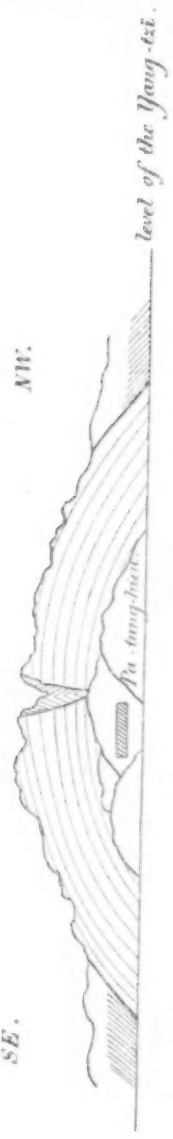


Fig. 6.

the three anticlines of the Wu-shan gorge. In this synclinal area occurs for the first time downstream since K'ui-chóu-fu besides the reddish-brown and the slaty limestone formations, the sandstone formation and that of K'ui-chóu-hien. After K'uan-tu-k'ou the Yang-tzĭ, much wider now, flows through a narrow ENE–WSW trending syncline, in the reddish-brown and the slaty limestone formations, until upstream from Wan-h'ou-two, it strikes a 30° south-dipping limb, and so again is turned toward the east and the south-east. Another bend in the trend of the layers is also observable in their dip. From the south-dipping layers the river is headed into north-dipping ones, which again become NE-dipping, the layers being thereby much fractured. Before Pa-tung-hien the dip is again toward the north and then northwest. Just below Pa-tung-hien the Yang-tzĭ cuts across the upper part of a local fold in the gorges-limestone formation, thus showing in the right river bank the section as represented in Fig. 6. It is still the same north-dipping limb of the most southerly Wu-shan gorge anticline; and the layers, dipping consecutively NW, N, and NE, plainly reproduce the fold in the limb.

The Yang-tzĭ then continues its way in the 30°–40° north-dipping layers of the reddish-brown formation, trending ESE–WNW, and then in the slaty limestone formation, which here has much diminished in thickness and individuality. Near the Niu-k'ou-t'an the river reaches the base of the sandstone formation, consisting of dark-green slaty sandstones. The river now flows almost in the trend of the layers.

Near Pa-t'ou-t'an, the right bank consists of the reddish-brown formation, above which still lie a few slaty limestone beds; the left bank is of the

sandstone formation, overlying which soon appears the K'ui-chóu-hien formation. Near Che-men then we see on the right bank the reddish-brown, on the left the sandstone and K'ui-cóuh formations.

We must observe the thinning out of the slaty limestone formation. A little farther downstream we see the layers to the right dipping south, and those to the left dipping north, and this fold goes from the right bank to the left just above the Yeh-t'an. This fold occurs in the reddish-brown formation, and thus we have come out of the northern limb into the anticline itself. If we now consider that the same anticlinal crest, which, a little above Fu-li-chi, was estimated at a height of some 500 m. in the gorges-limestone formation (Fig. 4) was at a height of 10 m. near Yeh-t'an in the stratigraphically much higher reddish-brown formation, then the conclusion is patent, *that this anticline of Pa-tung* (as I shall call it) *has greatly diminished in height from west to east.*

The sandstone formation near Yeh-t'an contains layers of coal, as is the case in the Red Basin itself. It rests on the fold in the reddish-brown formation and supports the K'ui-chóu layers. Immediately below the Yeh-t'an the fold commences to turn toward the south, and, going downstream, we find the NNE-dipping limb of the sandstone formation, to which soon succeeds the K'ui-chóu formation, trending already SE–NW with a dip NE. In the thick sandstone beds, about ten in number, of the K'ui-chóu formation which appear typically, especially on the left bank till close to K'ui-chóu, we see how the trend gradually becomes NS and the dip 60° east. This plainly shows *the deviation of the anticline of Pa-tung, which in general traits has an equatorial direction, to a meridional one, the convex side of the bend being turned toward the NE.* The significance of this deviation I have set forth on pp. 180, 181 of my *Géologie du Bassin Rouge*, where I wrote:

> Another deviation was observed upstream from K'ui-chóu; it is the one, to the south, of the anticline which extends from the middle of the Wu-shan gorge in a more or less equatorial direction toward the east. This deviation must have been caused by the powerful anticline of Nan-t'ou, about which later.

And again on p. 190:

> I must finally assume that the anticline of Nan-t'ou must have formed the line of resistance for the anticlines of the Red Basin, which, in its NE part trend

ENE–WSW. Very interesting in connection with this appears the deviation of the anticline, which extends from the middle of the Wu-shan gorge toward the east. This deviation takes place a little farther upstream, above K'ui-chóu, from a direction about EW to a more or less meridional one, so that the convex side is turned toward the NE. This fact shows, firstly, the capacity of resistance of the anticline of Nan-t'ou, which resistance would seem to me impossible, if a great fault[1] really existed. And, secondly, that the origin of the anticline of Nan-t'ou must date from before the folding of the Red Basin.

According to my idea the sinking from west to east and the deviation of the anticline of Pa-tung, have in the structural geology of the land, a very special and interesting signification, representing as they do the relation of a fold of the Red Basin with regard to the anticline of Nan-t'ou.

This deviation of the anticline of Pa-tung has not been observed by Willis. Pumpelly however does mention it, although this explorer also failed to observe its signification. Pumpelly[2] writes:

> The trend of the beds, which near the gorge (of Mi-t'an) was NNE, with a dip of about 40° to WNW, changes here to N with a dip to E and farther up opposite Kwei (K'ui-chóu-hien) it is N by W with an inclination of 70° E by N. Here is the beginning of a series of those angular plications so common to coal measures in all countries. Small beds of limestone and red argillite alternate with sandstone until, about two miles above Kwei, the first coal seems to crop out and with the appearance of these, the trend changes to NW by W, more than 90° from its normal direction of NE–SW.

If we look at the hills of the K'ui-chóu formation near K'ui-chóu, we see (as Fig. 7 shows) for the last time the indication of the Pa-tung anticline through steep ENE-dipping layers on the left bank of the Yang-tzĭ, by the beginning of the anticlinal arch in the top of the massive hilly landscape at the place, and through steep WSW-dipping layers in the hindmost hill-tops on the right bank of the river.

Below K'ui-chóu the trend of the layers is NNE–SSW, and the dip still steep ESE, but this soon becomes less, and it coincides with a decrease in height of the surrounding hills. Neither do the hard sandstone beds occur in the upper levels of the K'ui-chóu formation.

[1] This remark refers to my observation of the anticline of Nan-t'ou, in contrast with von Richthofen's *Gebirgsbruch bei I-tsch'ang*. Willis too remarks (p. 286 of his work): "von Richthofen was thereby led to consider it a fault-scarp, but there is no fault such as he inferred."

[2] *Smithsonian Contributions to Knowledge*, Vol. XV, "Geological Researches in China, Mongolia, and Japan," p. 6.

Near Lao-K'ui-chóu, a deserted place, on the right bank, we are in the synclinal area and then soon follow 45° WNW-dipping layers, and the river again enters into the levels of the K'ui-chóu formation, which here, however, do not contain so many sandstone beds as in the western limb of the syncline.

We must therefore remark the thinning out of the hard sandstone beds of the K'ui-chóu formation from west to east. And they no longer crop out so typically from the river banks as above K'ui-chóu-hien. Under the K'ui-chóu formation the river penetrates the slaty sand-

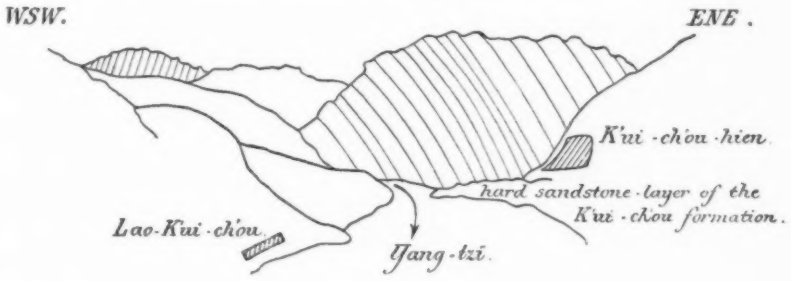


FIG. 7

stone layers of the sandstone formation, which has here greatly diminished in thickness and does not contain any coal measures.

We must observe the thinning out of the coal layers in the sandstone formation, and the thinning out of the formation itself toward the east.

Directly beneath the sandstone lies the gorges-limestone formation, which, rising up in an anticlinal limb, has again been transected by the Yang-tzï in a magnificent and grand gorge.

We therefore observe that the reddish-brown formation is also thinned out toward the east.

In the Mi-t'an gorge the Yang-tzï cuts across 30° to 40° WNW-dipping layers of the gorges-limestone formation. The massive mountains rise to more than double the height of these in the preceding sandstone area of Hsiang-chi. Only there, where a softer slaty layer complex occurs in this formation, we find a small valley on both sides of the river. This same layer complex, we shall see, plays an important part in the direction of the course of the Yang-tzï in the

I-ch'ang gorges. In the Mi-t'an gorge we see before us a west-dipping limb of the gorges-limestone formation, beneath which appears the green shale formation, "Blackwelder and Willis' Sin-t'an shale."

Between the Mi-t'an and Niu-kan-ma-fei or Ox-liver gorges, we find the Sin-t'an area. In about the middle of this area, which is bordered in the W, S, and E by the high gorges-limestone mountains, occurs the low and sharp fold of Lung-tchoe of which a photo appears on p. 43 of my publication on the Red Basin. This fold which has a 45° W-dipping and a 10° E-dipping limb, *itself dips steeply south* (see Fig. 8). It exposes a reddish-brown limestone, in which I found lower Silurian nautili, and many fine and very large Orthoceratite casts. I therefore believe that this must be the same limestone as the Ki-sin-ling limestone of Blackwelder and Willis. On this limestone rests the green shale formation (Sin-t'an-shale) and above that the gorges-limestone formation. All this as far as the right bank is concerned.

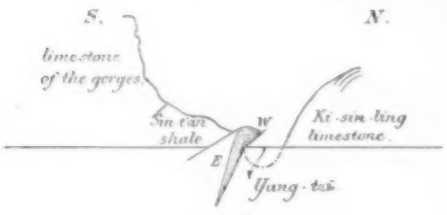


FIG. 8

On the left bank, on the contrary, the Ki-sin-ling limestone rises to much higher levels, and we find under the reddish-brown limestone a crystalline dark blue one, in layers, that are often separated by several centimeters, as a result of the plication. The closing of the narrow Sin-t'an basin by the gorges-limestone formation was not observed by me toward the north, looking from the right bank. We must still mention that, on the north bank, occurs, on top of the horizontally cut off and W-dipping Sin-t'an shales a thick conglomerate bed with large rounded-off pebbles, which must be originally from the valley in the north. This bed is of a recent date and was formed after the plication of the Red Basin, and while the Yang-tzī was cutting its way deeper and deeper into the mountains. In the eastern limb of the fold of Lung-tchoe the green Sin-t'an shale formation contains more hard quartzy sandstone beds than in the western limb. The formation also diminishes in thickness in that direction. The incline of the layers decreases and the Yang-tzī again enters the

overlying limestone formation, rising to mountain-heights, in which is cut the Niu-kan-ma-fei-hia.

In this gorge the dip of the layers soon again becomes W, and so, going down-stream, we find ever deeper levels, until, immediately after the end of the gorge near Miao-ho, the green shales reappear, but now in very much thinner beds.

This shale formation (Sin-t'an shale) thins out, in the western limb of the anticline of Nan-t'ou, from west to east.

The Ki-sin-ling limestone, which was exposed by the fold of Lung-tchoe, in the Sin-t'an area, does not again show itself east of the Niu-kan-ma-fei-hia.

As Blackwelder and Willis have observed in the upper course of the Ta-ning-ho the Sin-t'an shale to be in conformity with the Ki-sin-ling limestone, so that this limestone formation appears to extend as far as Sin-t'an, the thinning out of both formations toward the east would increase the signification of age of the anticline of Nan-t'ou. More about this later.

About the geoglogical structure of the Niu-kan-ma-fei-hia or Lu-kan gorge and the Mi-t'an gorge Willis again gives a description greatly differing from my own. He writes:[1]

> The Lu-kan gorge is a canyon across the Ki-sin-ling limestone, which dips NW. Above Sin-t'an the overlying middle Paleozoic shale, which we have named from its occurrence at this point, is succeeded by the Wu-shan limestone, dipping 40° NW and giving rise to the Mi-t'an gorge.

I presume that while going so swiftly downstream the fold of Lung-tchoe was overlooked, and so the whole structure was wrongly interpreted. According to Willis, a deep valley would have to occur between the two limestone formations. The photo on p. 43 of my *Géologie du Bassin Rouge* shows instead of a valley a high mountain range of gorges-limestone.

At the lower end of the Lu-kan gorge the trend of the layers is NNW–SSE. Underlying the but slightly developed green shale formation appear the crystalline schists, which trend NS and dip 20° W. They consist of mica, chlorite, and hornblende schists, alternating with nearly pure quartz beds and intersected by dykes of melaphyre. Near the lower opening of the Lu-kan gorge (Niu-kan-

[1] *Research in China*, Vol. II, Part 1, p. 286.

ma-fei-hia) there occurs a broad dyke of dioritic "Ganggestein" straight across the river, which, having left, by incomplete river-erosion, a couple of cliffs in the river bed, has caused the Kung-ling-t'an (a dangerous rapid).

A little way upstream from Mei-lin-to this crystalline schist formation stops, and it becomes apparent that it overlies a granite formation. The granite extends in a range of low rounded-off cliffs to the I-ch'ang gorge and northerly as far as one can see. Toward the south, however, we see the gorges-limestone mountains, which overlie the granite, stretching in one angular but continuous line to the next gorge.

This fact, taken in connection with a like occurrence in the Sin-t'an area, makes me draw the conclusion that there must have existed, to the south of Nan-t'ou,[1] a more or less equatorially trending fold, which therefore stretched about vertically on the anticline of Nan-t'ou. The synclinal area, which, according to my view, and in connection with this fold, exists to the south of the Yang-tzĭ shows a continuous gorges-limestone formation, both near Sin-t'an with the steeply S-dipping fold of Lung-tchoe, and between the Lu-kan and I-ch'ang gorges. The anticlinal parts, which, in connection with the foregoing, must have existed to the north of the Yang-tzĭ have disappeared through erosion.

This continuation of the gorges-limestone formation overlying the granite south of the Yang-tzĭ is not reproduced on Willis' map.

Pumpelly, on the other hand, writes:

> In the immediate neighborhood of the river, over an area of forty or fifty square miles, the limestone has disappeared but, in the distance, on both sides of the Yang-tzĭ, its yellow cliffs are seen towering to a height of more than 2,000 feet above the water.

As far as the granite area extends, the course of the Yang-tzĭ shows, with regard to the anticlinal axis which must run through it, a typically symmetrical line, which consists of two, about equally long WNW–ESE pieces, connected by a bend toward the south. In the middle part of the granite area there occur many dykes trending

[1] On the map of my *Géologie du Bassin Rouge*, Nan-t'ou has not been given the right location as is also not the case in the map of Yi-tschang-fu (*Plankammer der Königl. Preuss. Landes*, Aufnahme), from which it was copied.

about N–S of aplite, pegmatite and melaphyre, which have only been partly eroded in the river bed, thus leaving obstacles, which give rise to rapids.

As I already found occasion to remark in my former publication, these dykes of eruptive matter in the granite and crystalline schists, I bring into genetical connection with the plication of the anticline of Nan-t'ou.

Just below Nan-t'ou finally begins the last or I-ch'ang gorge. Pumpelly[1] here mentions to the east of the granite area of Nan-t'ou, once more metamorphic strata and says: "Those to the eastward, which could not be closely examined, seemed to be gneiss trending E–W and dipping about 30° to S."

Blackwelder[2] relates the following about a formation named by him "the Nan-t'ou formation" which is indicated on Willis' map to the north of the Yang-tzï:

> On account of the absence of fossils the age of the Nan-t'ou formation is not accurately known. It lies at the base of the Cambro-Ordovician limestone from which we obtained lower and middle Cambrian fossils within less than 100 miles, 160 km., from Nan-t'ou. Hence it is highly probable that these glacial beds on the Yang-tzï are of early Cambrian age.
>
> Little is known at present regarding the areal distribution of the Nan-t'ou glacial beds. The horizon at which they occur is exposed many miles both north and south of the Yang-tzï, at the base of the escarpment which is crowned by the Cambro-Ordovician limestone; but the river crosses it at one point only and we had no other opportunity to see it. At the lower entrance to the Lu-kan gorge Pumpelly examined the base of the limestone system, and reported 50 feet, 15 m., of quartzite, overlain by limestones, which contain layers and lenticular masses of flint. It is probable therefore that the glacial beds do not occur in that locality.

I have not observed anything of all this, and only saw that the gorges-limestone rests direct on the granite which may eventually have become gneissy. "The glacial beds of early Cambrian age," I am, however, at a loss to reconcile with my own observations.

The first portion of the I-ch'ang gorge shows 10° SE-dipping layers, which the river crosses almost vertically. At the same place, where a diminution in the incline of the layers occur together with their more slaty condition, the Yang-tzï bends round to the SSW.

[1] *Smithsonian Contributions to Knowledge*, Vol. XV, p. 4.

[2] *Research in China*, Vol. I, Part 1, p. 264.

In the Mi-t'an gorge we saw that this level of the gorges-limestone formation was steeply inclined, and on both sides of the river had been excavated into deeply grooved cross valleys. In the eastern limb of the Nan-t'ou anticline which has a much fainter dip, the river has completely altered its course, where it reached this softer level in the hard limestone formation. Afterward it again bends round to an ESE course, and cuts through ever-higher levels of the gorges-limestone formation, until, at the end of the I-ch'ang gorge, it makes a sharp curve to the south. In this latter part of the gorge occur many minor plications in the layers which, as a whole, continue to dip 10° SE. The limestone strata, gently sloping away, disappear under the I-ch'ang series.

Although I did not perceive it, Willis again assumed the existence of the Sin-t'an shale and the Ki-sin-ling limestone in the I-ch'ang gorge. He writes:

> The lowest or I-ch'ang gorge of the Yang-tzī is cut across the Wu-shan limestone which rises at the rate of about 1,000 feet a mile till the Sin-t'an (middle Paleozoic) shale appears from beneath it. Further upstream the Ki-sin-ling (Cambro-Ordovician) limestone forms a second gorge, and passing from a dip of 10° to a nearly horizontal position, gives rise to the mesa like heights above Huang-ling-miau.[1]

But the deep erosive valleys in the Sin-t'an shale altogether fail to prove that the above quoted view of the structure of the I-ch'ang gorge is correct. The photo published by me on p. 25 of my *Géologie du Bassin Rouge* shows high rising cliffs of limestone on the left side of the Yang-tzī, where, according to Willis, a deep erosive valley of Sin-t'an shale ought to exist. My photos on p. 28 sufficiently prove that Willis' idea, that the Ki-sin-ling limestone borders the right side of the Yang-tzī from Nan-t'ou till Huang-ling-miau, is not in accordance with the reality.

Below the I-ch'ang gorge the Yang-tzī enters upon its lower course, and, to far below I-tu, it cuts across a formation of sandstone and red argillite layers, which between I-ch'ang and I-tu are folded into a broad and flat anticline.

Blackwelder calls this "apparently a recurrence of the K'ui-chóu formation."[2]

[1] *Research in China*, Vol. I, p. 286.

[2] *Op. cit.*, p. 287.

In the *Géologie du Bassin Rouge*, pp. 163, 164, I remarked concerning this:

> Although the formation of I-ch'ang misses the characteristic appearance of the K'ui-chóu formation, we may safely presume that both are of the same geological age, especially as concerns the formation of I-ch'ang and the upper levels of those of K'ui-chóu. In the syncline of Lao-k'ui-chóu we have observed similar red and white more or less sandy argillites and we might imagine that the coarser material was deposited in the Basin, while the finer matter was collected on the outside.

Finally I must still mention the occurrence of a thick conglomerate bed with pebbles of a size ranging from that of a marble to that of a fist and more, which is found on both sides of the river above the present water level, and which point to an old river formation. It therefore dates after the plication of the Red Basin, and has been formed by the action of the hydrographical system, which appeared after the plication.

According to my idea Pumpelly has wrongly interpreted the signification of the conglomerate layer. He writes:

> Near the city of I-ch'ang, at the eastern mouth of the gorge, the limestone strata, trending here NE and dipping about 80° to SE, are covered by apparently conformable beds of fine-grained gray sandstone, which toward the top soon merges into a coarse conglomerate. . . . . This conglomerate is followed by a red sandstone, which, above I-tu, dips easterly, and below that place westerly.[1]

Hence Pumpelly considers this conglomerate as a level in the I-ch'ang formation.

From K'ui-chóu to I-ch'ang, the Yang-tzī thus cuts through the high mountain ranges, here rising to 1,200 m, which form the boundary between the Red Basin of Ssī-ch'uan and the East China plain. The structure of these mountain ranges, may appear clear from the geological map and the different sketches. The deep gully, cut out by the Yang-tzī in these ranges exposes a succession of the finest and most interesting pictures of its inner structure. It is, as we see, a succession of folds, in which faults only play a secondary part.

The above suggests the following questions which I shall consider consecutively:

1. The tectonic signification of these folds.

[1] *Smithsonian Contributions to Knowledge*, Vol. XV, "Geological Researches in China, Mongolia, and Japan," p. 7.

2. The signification of the anticline of Nan-t'ou.

3. The causes which have enabled the Yang-tzī to cut through these high-limit ranges.

Concerning the first point I must remark that the folds here are not sinial folds taken in the sense von Richthofen attached to old Paleozoic ENE–WNW trending folds, in North China (Liau-tung). The folds[1] of the Red Basin of Ssī-ch'uan are of much younger date, in fact, younger than the K'ui-chóu formation, which has been plicated together with the lower layers. The almost equatorial trend in the easterly border area of the Red Basin I have already explained through the deviation of these later folds against the so much older folded mountain ranges of the Tsin-ling-shan and Kuen-lun. In the *Monatsberichte* of the German Geological Society, No. 9, p. 202, I wrote:

> We can therefore describe that part of the earth's crust in southwest China in the following manner: Firstly, in the south a widely extending upheaval of the earth's crust in broad, flat folds; then, toward the north an increase in height and number of the regular and parallel folds; finally, the deviation of the whole series from the NNE–SSW direction, to an ENE–WSW and EW one, in consequence of the "Anschaarung" of this system of folds against the equatorially trending Kuen-lun or Tsin-ling-shan system.

Formerly I wrote concerning this:

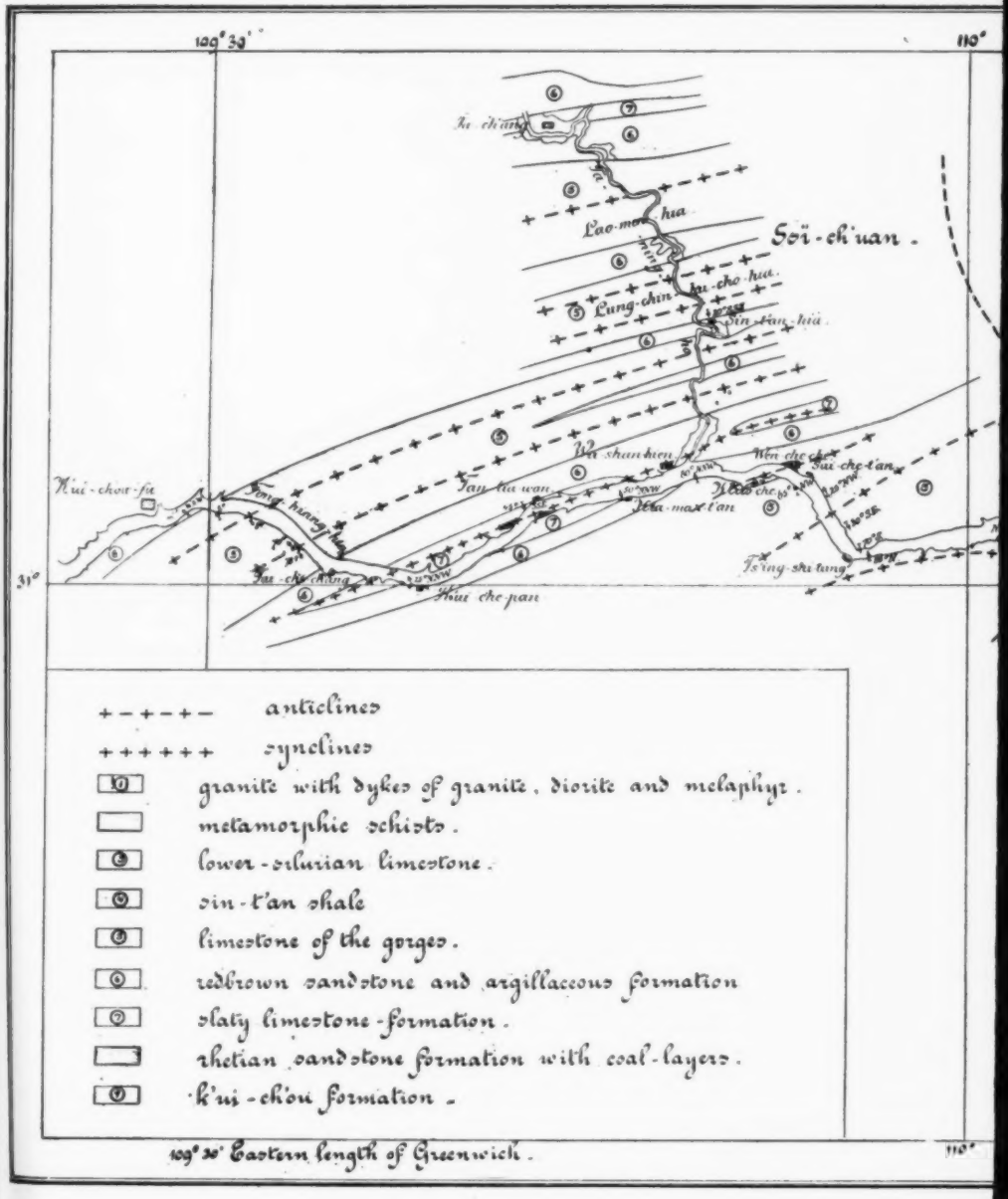
> It is quite possible that this pressure will have left visible traces north of Wu-shan and K'ui-chóu-fu in this old mountain range (the Tsin-ling-shan).[2]

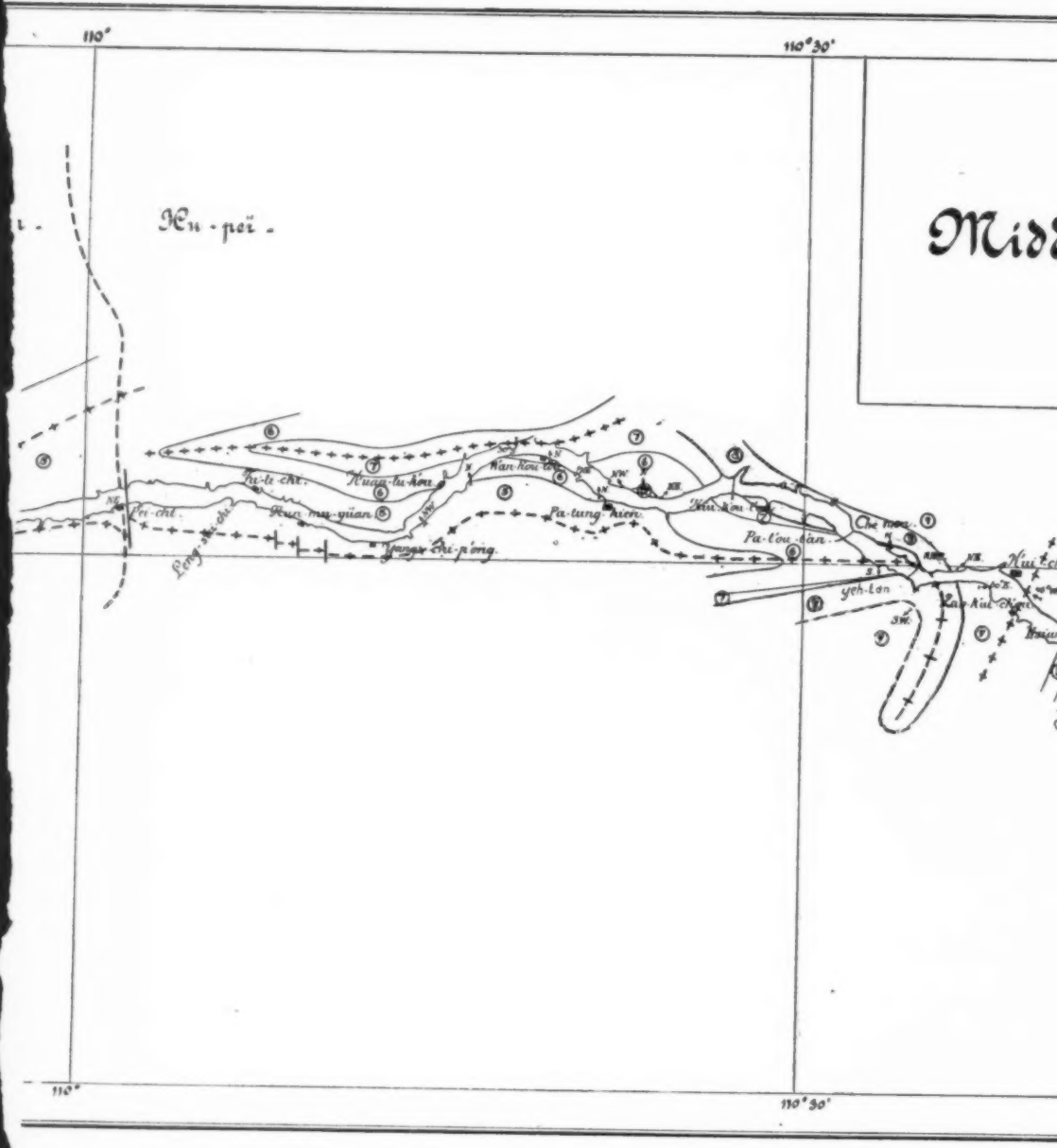
As a fact Willis, who passed through the land north of Wu-shan, along the Ta-ning-ho, gives, in his oft-mentioned work (pp. 288, 289) a section, which shows that the folds, from S to N, to the north of the Yang-tzī, become more and more sharp and high, while, finally, a little to the north of Sü-kia-pa, 65 km north of Wu-shan, he depicts a great overthrust, about which he writes (p. 291):

> Northward from Sü-kia-pa, there is, however, a complexity of structure which we did not fully understand in the field, but now interpret as an overthrust fault.

[1] Whether these folds are younger or older than those of the Jura mountains cannot be said for the present moment; but we may point out that they very materially output the latter as concerns regularity and simplicity.

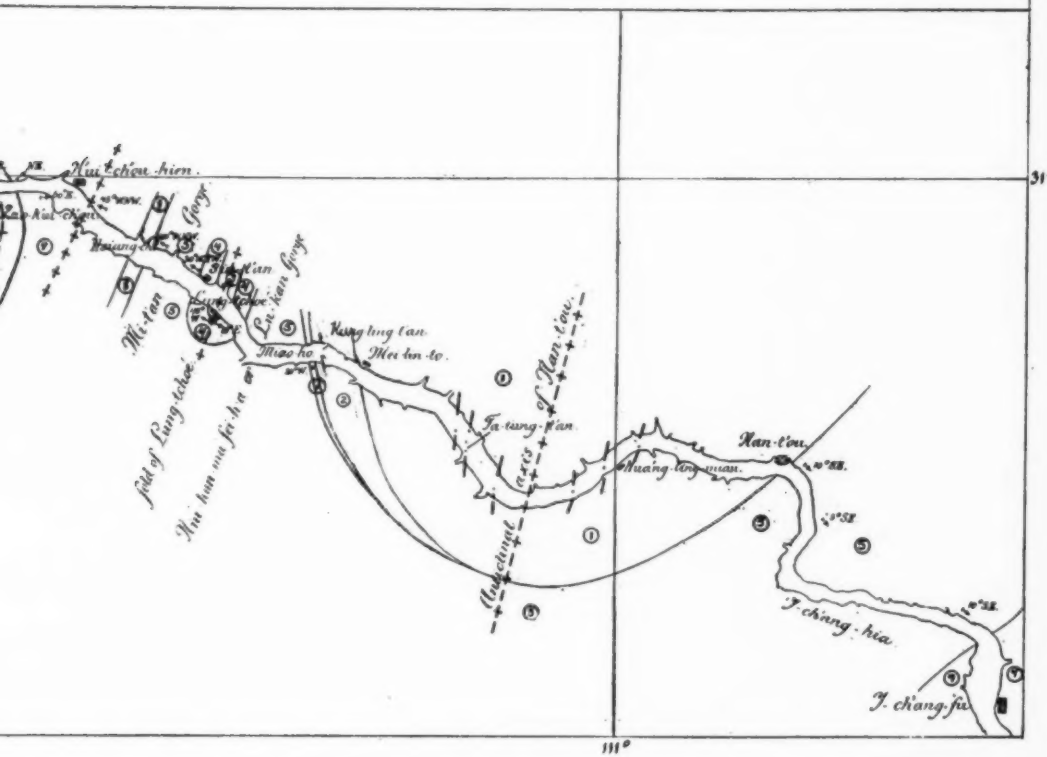
[2] *Géologie du Bassin Rouge*, p. 181.


109° 39'
110°
Soï-ch'uan.
Lao-mo-hia
Lung-chin-hu-cho-hua
Yin-tien-hia
Wa-shan-kien
Wen-che-chi
Sui-che-t'an
Yan-tia-wan
Hsia-mao-t'an
Tsing-shi-tung
Hsui-che-pan
Kiui-chou-fu
Yang-hung-hua
Yan-chi-ming
31°
+ − + − + − anticlines
+ + + + + + synclines
granite with dykes of granite, diorite and melaphyr.
metamorphic schists.
lower-silurian limestone.
sin-t'an shale
limestone of the gorges.
redbrown sandstone and argillaceous formation
slaty limestone-formation.
rhetian sandstone formation with coal-layers.
k'ui-ch'ou formation.
109° 30' Eastern length of Greenwich.
110°


110°
110° 30'
Mid
Mu-pei
Pa-tung-hien
Pa-t'ou-kan
yeh-kan
Kiu-Kiang
110°
110° 30'

Geological map of the Middle Yang-Tzï-Kiang gorges.

Scale 1 : 250.000 ~



From the foregoing it is clear that I cannot agree with the views expressed by von Richthofen[1] in the following quotations:

In this way it becomes plain that an immense area, situated to the south of the easterly Kuen-lun, whose basal structure in the parts known to us (and probably in its entirety), consists of the paleozoic formations, and which is folded together according to the sinial trend of the strata, can yet show great variety in its separate parts

Although I fully agree with the description of the geological structure given in the next passage, I can by no means agree with the example von Richthofen adduces to illustrate the event of the welding together of the Kuen-lun mountains with the southern system of plication. On p. 638 we read:

One of the most remarkable circumstances is the firmly growing together of the sinial zone of plication with that of the Kuen-lun in the Tsin-ling-shan. Just as when upon a cloth, folded into parallel folds, were laid a heavy bar at an oblique angle to the direction of those folds, and this bar were moved, at right angles, to its axis toward those folds until they were so bent round as to completely take the direction of the bar, in the same way the stiff stem of the Kuen-lun leans against the sinial folds. While at a distance from the Kuen-lun they strike from SW to NE, they gradually bend round toward the Kuen-lun, to a WSW–ENE trend. At the same time they press so closely, and the strata attain such a steep dip, that they become joined with the principal stem into one solid mass.[2]

From this example of the bar on the folded cloth we might draw the conclusion that von Richthofen assumes that the Kuen-lun mountains are of later formation than the area to the south of it, considered by him as occupied by mountain ranges folded up according to the sinial system. I need not reiterate what I wrote above, for I

[1] *China*, Vol. II, p. 637: "So erklärt es sich, dass ein ausserordentlich ausgedehntes, im Süden des östlichen Kwen-lun gelegenes Gebeit, dessen Grundbau in den uns bekannten Theilen, und wahrscheinlich in seiner Gesammtheit, aus paläozoischen Formationen besteht, und nach der sinischen Streichrichtung zusammen gefaltet ist, doch in seinen einzelnen Strecken grosze Verschiedenheit darbietet."

[2] *China*, Vol. II, p. 638: "Zu den bemerkenswerthesten Umständen gehört das feste Verwachsen der sinischen Faltungszonen mit denen des Kwen-lun im Tsin-ling-shan. Wie, wenn man einen schweren Stab auf ein in parallele Falten geworfenes Tuch unter schiefem Winkel zur Richtung dieser Falten legt und ihn gegen dieselben hin rechtwinklig zu seiner Axe fortscheibt, die Falten sich bis zur völligen Anschaarung umbiegen, so schmiegt sich der starre Stamm des Kwen-lun an die sinischen Falten. In grösserem Abstand von ihm von SW nach NO gerichtet, biegen sie an ihm zu einen WSW–ONO Streichen um! Zugleich drängen sie sich so dicht, und die Schichten nehmen eine so steile Stellung an, dass sie sich zu einer einzigen starren Masse mit dem Hauptstamm verbinden."

made it clear enough there that I believe the relation to have been exactly the contrary, namely: an older Kuen-lun range, against which the almost meridionally directed recent folds of the Red Basin struck —like the surf of the ocean beating against the firm land—thereby causing them to rise and to bend round, and thus to assume, only locally and incidentally, a trend in accordance with that of the sinial system of folding.

Another confirmation of my idea of the forcing-up of the Red Basin folds, as I was able to observe it in the northeastern parts, I find far to the westward, described in the following communication by von Richthofen:

> The outermost southern branch of the sinial system, which to the south of Kwang-yuen is still hidden under the formations of the Basin (see Fig. 111*c*) now appears in ever mightier lines, striking at first WSW and then SW, and forms (as beforesaid) the lofty northwestern wall of the plain of Tschöng-tu-fu. It here bears the name of San-miën-shan and Kiu-ting-shan.[1]

According to my opinion, the tension, which caused the Red Basin to be folded and to be pressed up against the Kuen-lun, became less in this westerly part, so that a basin fold still could be deviated by the Kuen-lun from its normal direction but at the same time (the fold) became flatter and vanished, instead of running high up against the Kuen-lun mountains, as is the case in the eastern part.

As concerns the signification of the Nan-t'ou anticline, we may conclude from the foregoing:

1. The crystalline schists are found to the west of the granite area of Nan-t'ou. Originally they will also probably have occurred to the east, but they are washed away, while sediments were deposited in a basin forming itself to the westward.

2. To the visibly oldest sediments belongs my lower Silurian brown limestone of Sin-t'an, with its fossils, the Cambro-Ordovician Ki-sin-ling limestone of Blackwelder and Willis. As we saw, this formation does not extend as far to the east as the lower entrance of the Ox-liver gorge. It does not seem to occur to the east of the Nan-t'ou anticline.

[1] *China*, Vol. II, p. 639: "Der äusserste Südzweig des sinischen Systems, welcher nördlich von Kwang-yuen noch unter den Beckengebilden verschwindet (fig. 111*c*) hebt sich in seinen erst nach WSW, und dann nach SW gerichteten Streichen immer mächtiger hervor und bildet wie erwähnt, die erhabene Nordwestmauer der Ebene von Tschöng-tu-fu. Er führt hier die Namen San-miën-shan und Kiu-ting-shan."

3. In transgression for some kilometers toward the east we find my green shale formation, Blackwelder's middle Paleozoic Sin-t'an shale, which thins out not far to the east of Miao-ho at the lower entrance of the Ox-liver gorge. To the east of the Nan-t'ou anticline this formation does not seem to occur either.

4. To the Sin-t'an shale succeeds my gorges-limestone formation, Blackwelder's Upper Carboniferous Wu-shan limestone.

Now we see the remarkable fact that the Nan-t'ou area, which proved to be an eastern land-ridge for the older formation, becomes a sea, together with the eastern part, during the Upper Carboniferous period. *This sea very probably in transgression spread over a great part of China.* After the limestone formation the area of Nan-t'ou again resumes its rôle of boundary wall between an eastern and a western basin.

5. The (probably) Permian and Lower Triassic reddish-brown formation only occurs in an eastern part of the Red Basin, not in its center. It extends along the Yang-tzï as far downstream as Yeh-t'an, but not as far as Hsiang-chi.

6. The (probably) Upper Triassic slaty limestone formation extends even less far toward the east. It thins out already above Yeh-t'an. Neither of these formations occur to the east of the Nan-t'ou anticline.

7. Overlying this transgrades the Rhetian sandstone formation in the Red Basin itself far to the west. Although the area of Nan-t'ou is again a land limit against which the sandstone formation thins out, this same Rhetian sandstone, which contains coal measures, occurs in the East China Basin and also in other parts of China. We already noticed before that the formation itself extends farther east than the coal layers, which occur in higher levels.

8. This retrogression of the sediments westward is continued, and we find the shell-marl strata of probably Cretaceous age only in the middle of the Red Basin, whilst it thins out in more or less extensive lenticular layers between Wan-hien and K'ui-chóu-fu.

9. After this again comes a period of transgression. The K'ui-chóu formation extends to the western limb of the Nan-t'ou anticline. It seems that this anticline did not act as dividing line for the upper levels of this formation, for we find the I-ch'ang formation overlying its eastern limb, as far as it has not been washed away by ero-

sion. The very highest level which consists of very coarse-grained and micaceous sandstone, however, again only occurs in the center of the Red Basin.

In resuming the above we must come to the important conclusion that the area of Nan-t'ou must have played the part of a dividing line ever since the Cambro-Ordovician, or perhaps still earlier ages, until after the depositing of the K'ui-chóu formation (Cretaceous formation or later?). During all that time, however, it twice gave up this rôle: once during the Upper Carboniferous and for a second time, let me say, during the upper K'ui-chóu time. At last the broad mighty anticline of Nan-t'ou was completely formed as we see it nowadays, partly destroyed by erosion.

The later formed folds of the Red Basin are therefore of younger date, and although we might assume an earlier date for the beginning of their growth, which a more careful research may possibly teach us from the trend of the extension of the reddish-brown and the slaty limestone formations, it must be inferred that their growth proper must have taken place much faster than that of the Nan-t'ou anticline.

As I already remarked above, these NNE–SSW folds of the Red Basin are bent up against the Tsin-ling-shan which I regarded as the consequence of the Red Basin having been pressed to the north.

Finally, I again refer to the deviation of the anticline of Pa-tung against that of Nan-t'ou, which fact agrees with the greater age and capacity of resistance of the latter.

And now I have still to consider the question of what were the reasons which caused the hydrographic system that originates nowadays on the eastern slope of the highlands of Tibet south of the Kuen-lun mountains, to force its way through the high mountain ranges from K'ui-chóu-fu to I-ch'ang. Until the present moment I have not fully considered this point. In the literature that I have consulted, on this subject I only find an explanation from Arthur Kniep[1] which, however, seems so strange to me that I shall not discuss it here.

[1] "Der Yang-tzī-kiang als Weg zwischen den Westlichen und Ostlichen China," *Gerlands Beiträge zur Geophysik*, Band VII, Heft I, pp. 22, 23. The explanation of

Of all the existing theories those of antecedent and regressed or beheaded rivers seem the most probable to me. Even in a developed and grand river system as that of the Yang-tzī-kiang it seems quite possible that both factors combined to produce such a system.

When we look at the map of China, we are impressed by the fact that the whole basin of the Upper and Middle Yang-tzī finds an outlet through the most northerly area which borders, to the south, the high dividing mountain range of north and south China. It readily appears to us that whilst the Kuen-lun is the divide between the Upper Yang-tzī and the Upper Hwang-ho, its eastern prolongation, the Tsin-lin-shan, remains the divide of a southerly developed Yang-tzī system and a northerly developed Hwang-ho system. Thus, in very general features, facts can be understood by a glance at the map.

But to return to the Middle Yang-tzī itself. We must first of all bear in mind that the anticlines of the Red Basin, and with them, of course, its entire area decline from N to S. This fact must be inferred from the observations that in consequence of an intensive erosion the anticlines in the northern parts of the Red Basin have been weathered away to a thickness of at least 2,500 m. down the gorges-limestone, which now still rises in mountains of 1,500 m. and more. These arch cores of limestone are only to half their height concealed under anticlinal limbs of the younger formations. More to the south the limestone cores have lowered to the level of the Yang-tzī and the cores of the sandstone formation, lying over the limestone, rise to anticlinal ridges of some 300 m., whilst there the overlying mighty K'ui-chóu formation has been washed away and has only remained in place in the synclinal areas, where it is dissected by numerous narrow cross and length valleys. At last, south of Ki-kiang, a place some 100 km. in right line south of Chung-king, I encountered an anticline which up to the height of 500 m. still consisted of the youngest or K'ui-chóu formation, the sandstone formation there being very much lower than it is in the country of Chung-king.

the antecedent theory, to which I shall also appeal, seems to him very improbable. Kniep speaks of a peneplain between Wan-hien and I-ch'ang, where the Ta-kiang (a local name for this part of the Yang-tzī) should have taken its meandering course without close connection to the rock structure.

Thus, when we appeal to the antecedent theory we must accept the fact that this antecedent river not only had the power of cutting its course through a succession of parallel folds but even could keep the better of a general rising of the land contrary to its way from south to north, from far upstream Chung-king till Wan-hien. Nothing opposes itself to this combined movement of the earth's crust, viz., its being folded and at the same time pressed up against the Tsin-ling-shan; on the contrary the observations lead to this inference as is explained in the above. To account for the last-mentioned discrepancy we must suppose that the river had a sufficient power, as the result of a considerable fall anywhere in its course and that there was no possibility of going another way, for a river does its work only when it is forced to it. Now, it is almost certain that east of I-ch'ang, where nowadays still exists the low east China plain with its many lakes (Tung-ting, Po-yang, etc.,) ever since the filling up of the Red Basin there was a considerable difference in height from west to east. Might any obstruction have occurred in the antecedent river by the rising of the country from south to north, it still would be possible that a more intensive erosion in the watercourse took place from I-ch'ang in an upriver direction. But here we already appeal to the regression theory, for it may be that the rate of land-folding and uplifting have been the same as that of the cutting-power of the river water, or the first may have stopped the last till regression of the old watercourse redressed the former river-way, which then could continue its work in the old direction.

As to the second condition necessary for the absolute maintenance of the antecedent theory, viz., the impossibility for the river water of going another way, we cannot say very much because of the very incomplete geographical and geological investigations of southern China. When we look at the map we see that all great tributaries of the Yang-tzĭ, and its headwaters too, run in general lines from north to south. This makes me feel quite inclined to suppose that the hydrographical system of the province Ssĭ-ch'uan once must have found an outlet toward the south according to the general incline of the earth's surface from north to south. If this is true, then we must consider one or more of southwestern China's big rivers as beheaded ones by a retrogressed river system, which now is that of the Middle

Yang-tzī. That the effect of retrogression proved to be most powerful as near as possible to the Tsin-ling-shan appears most natural. The open sides of the Nan-t'ou and Sin-t'an areas toward the north quite accord with a retrogression theory for this last part of the Middle Yang-tzī.

All the grand gorges of the Middle Yang-tzī are very interesting when one could see in them the fixed image of the relation between the rate of movement of the earth's crust in the folding process and of the cutting-power of a river. Although from Chung-king to I-ch'ang the Yang-tzī cuts through the anticlinal mountain ranges nearly perpendicularly, there is a sufficient number of exceptions, for instance, where the river has a meandering course in the gorges; so from this point of view we cannot find either a proof to support the antecedent theory, nor one against it. The indifference of the Middle Yang-tzī to the general land-structure, rising from south to north, might account to the antecedent theory. On the other hand the bending round of the Yang-tzī, near Wan-hien, from a general NNE to an ENE course, in complete correspondence to the turn of the anticlines of the Red Basin against the Tsin-ling-shan, seems to bear against this theory, for here the river has followed the mountain structure. If there has been any antecedent watercourse in this region, it must anyhow have been considerably affected by the folding process, probably being restored only after a retrogression process of a watercourse more downstream from this point.

From the above it is clear that by reason of the present condition of the investigation of the whole of the Yang-tzī basin we cannot come to a decisive opinion to attribute the origin of the grand gorges of the Middle Yang-tzī-kiang either exclusively to the antecedent river theory or to that of the retrogression process.

Contrary to Kniep, however, I must point out that the meanders of the Yang-tzī in the synclinal valleys and even in the eastern limb of the Nan-t'ou anticline were exclusively caused by the geological and the rock structure. Another important example of this kind can be seen in the part of the river between Wan-hien and K'ui-chóu-fu, where the Yang-tzī, having lowered its course to one of the thick sandstone layers of the K'ui-chóu formation, here being in a horizontal

position, has cut its way in a straight canal-like bed, obliged to do so by the rock structure.

The Middle Yang-tzī might be called a mature river, and this even after it has been revived, as seems to have been the case only once. The conglomerate bank of principally eruptive pebbles, mentioned above, shows the remains of the floor of a former Yang-tzī valley, in which the river has cut its narrower trench of nowadays. The mighty work here already accomplished by Nature has rendered the Yang-tzī navigable to far above Chung-king, thus making it for a length of more than 2,500 km. one of the most important highroads for traffic. That which Nature has left undone would be no serious obstacle for the amelioration of this waterway because the obstructions do not consist of falls, but only of rapids as the result of not-yet-washed-away detritus accumulations and partly uneroded dykes of eruptive rocks in the Nan-t'ou granite area. These obstructions, that make steam navigation on the Middle-Yang-tzī not yet economically practicable, can, according to my idea, easily be overcome by human technics, and it is by no means beyond financial possibility. This has already been set forth in detail by me in an article, "La navigabilité du haut Yang-tzī-kiang par bateaux à vapeur," published in the *Revue universelle des Mines*, at Liège, tome XII, 4e série, p. 149.

No doubt the geology of the mountain ranges which are cut by the Yang-tzī between K'ui-chóu-fu and I-ch'ang still offer many interesting problems and points of view. But I believe to have given in the foregoing, in general features, the geological structure of this most interesting area as it appears in reality. Indeed, all that I saw of the Red Basin of Ssī-ch'uan and its border parts, leads me to the conviction, that, as for structural geology, this is one of the classic parts of the earth's crust, showing its inner and outer structure in a way to allow of the finest detail studies of folding and erosion, which appear in a pattern of the utmost simplicity and regularity.

RECENT STUDIES IN THE GRENVILLE SERIES OF EASTERN NORTH AMERICA[1]

FRANK D. ADAMS
McGill University, Montreal.

In a paper which has recently appeared[2] a summary of the chief results of a geological study of a large area on the margin of the Laurentian protaxis in eastern Ontario, by Dr. Barlow and the writer, has been presented. The area in question, whose study has just been completed, is one of the largest areas of the protaxis which has hitherto been examined, comprising 4,200 square miles, and the study has furthermore been carried out in much greater detail than in the case of areas formerly examined in Canada, the field work extending over a period of eight years. In a second paper[3] now in press a more detailed account of the great development of nepheline and corundum-bearing syenites found in the area is given.

The area lies near the border of the Laurentian protaxis, north of Lake Ontario and east of Lake Huron, and one of the most conspicuous features of its geology is the great development in it of Logan's Grenville series. It is proposed in the present paper to present certain new facts which have been discovered concerning this series in the area in question, as well as certain general considerations relative to this, which is one of the most extensive and important series of pre-Cambrian Age in North America. A complete description of the area will appear in the form of a report to be issued by the Geological Survey of Canada during the present year.

In *The Geology of Canada*,[4] published in 1863, which contains a statement of the results of the work of the Canadian Survey up to that date, Logan commences the chapter dealing with these rocks as follows:

[1] Communicated by permission of the Director of the Geological Survey of Canada,

[2] Frank D. Adams, "On the Structure and Relations of the Laurentian System in Eastern Canada," *Quarterly Journal of the Geological Society*, May, 1908, p. 127.

[3] "On the Nepheline and Alkali Syenites of Eastern Ontario," *Transactions of the Royal Society of Canada*, 1908.

[4] P. 22.

The rocks which compose the Laurentian Mountains were shown by the Geological Survey in 1846 to consist of a series of metamorphic sedimentary strata underlying the fossiliferous rocks of the Province. They have since been recognized by Sir Roderick Murchison as forming the so-called "Fundamental Gneiss" of the western islands of Scotland and parts of Rosshire and Sutherlandshire, and the name of the Laurentian system as applied in Canada has now been extended to them in Great Britain where, as well as in this country, they are the oldest rocks known and lie at the base of the sedimentary series. They are highly altered to a crystalline condition and are composed of feldspathic rocks interstratified with important masses of limestone and quartzite. The great vertical thicknesses of the series are composed of gneiss containing chiefly orthoclase or potash feldspar, while other great portions are destitute of quartz and composed chiefly of a lime soda feldspar, varying in composition from andesine to anorthite and associated with pyroxene or hypersthene. This rock we shall distinguish by the name of anorthosite.

Logan's exploratory work showed that these ancient rocks underlie enormous areas in Canada. It is now known that they occupy an area of about two million square miles. As their structure is very complicated, he found it impossible to make a detailed study of the whole Canadian shield and therefore decided to select a comparatively limited area in which the Laurentian system had a typical development, and there, by careful mapping, to ascertain its structure and relations. The district which he selected had an area of about fifteen hundred square miles and was situated on the margin of the northern protaxis in the vicinity of the little town of Grenville, some forty miles to the west of the city of Montreal. His map of this area appeared in the atlas which accompained *The Geology of Canada*. This area has come to be known as the "Original Laurentian Area" of Logan, and the succession which he worked out there has found its way into most textbooks.

Since that time other members of the staff of the Geological Survey of Canada, notably Vennor and Ells, have extended our knowledge of this portion of the Laurentian area by mapping large tracts along the margin of the protaxis to the west of the Original Laurentian Area as far as the western border of the Province of Quebec, and thence over into eastern Ontario. In 1897[1] the writer published the results

[1] "Report on the Geology of a Portion of the Laurentian Area lying to the North of the Island of Montreal," with appendices and map, *Annual Report of the Geological Survey of Canada*, Vol. VIII, p. 184.

of a study of a large area lying to the east of the Original Laurentian Area and extending as far as the St. Maurice River, which flows into the St. Lawrence about half-way between Quebec and Montreal. Our knowledge of the Laurentian has also been very considerably extended by the researches of Kemp, Cushing, and others in the Adirondack Mountains, as well as by the extended explorations of Low and others in the far north and by the work of Lawson in the west.

SIR WILLIAM LOGAN'S WORK IN THE LAURENTIAN OF CANADA

Before considering the results of these recent studies it will be of interest to look very briefly at the work done by Logan in the Original Laurentian Area.

This master of stratigraphy found that the Laurentian system, instead of presenting a chaotic mass of crystalline rocks from which no order could be evolved, constituted as a matter of fact a great series of rocks largely stratiform, if not stratified, in character, and which almost everywhere exhibited a foliated structure. Among these rocks he found great bodies of limestone, the importance and significance of which he at once recognized. This limestone was, it is true, frequently very impure and always coarsely crystalline, constituting in fact a true marble. Its chemical composition, however, led him to conclude that it was of sedimentary origin. The limestone occurred in the form of belts or bands, and, being easily recognized in the field, was used by him as a basis for working out the complicated stratigraphy of the district. Being soft and easily disintegrated, it frequently occupies low drift-covered ground, and over considerable tracts of country he was obliged to determine its existence beneath the drift by driving down a sharply pointed iron rod and testing the powder brought up by the rod, by means of acid. He was enabled by the use of this geological cheese-taster to determine the existence of the limestone beneath the drift in many places where its occurrence could not be otherwise ascertained.

Associated with the limestones he found in places bands of quartzite. Bands of hornblendic rocks, now termed amphibolites, often of great thickness, also formed part of the series. He ascertained, however, that orthoclase gneiss was the most abundant rock in the Laurentian. This, he states, varies greatly in character, being

sometimes almost massive and granitic, while elsewhere it is well foliated. It sometimes occurs in great bodies free from all admixture of other rocks, while at other times it is found intimately associated or interbanded with the limestones or other rocks making up the series.

The highly contorted character of this series of rocks made it very difficult to determine its thickness, but Logan regarded the following ascending section as representing approximately the succession and thickness of the various elements constituting the Laurentian in the original area examined by him.

		FEET
1.	Anorthosite, above the Morin band of limestone, the thickness is wholly conjectural	10,000
2.	Orthoclase gneiss, passing gradually into anorthosite, probably includes the quartzite of Quartz Mountain, the anorthosite above it and the gneiss of passage	3,400
3.	Proctor's Lake limestone	20
4.	Orthoclase gneiss	1,580
5.	Crystalline limestone of Grenville, in some parts interstratified with a band of gneiss about	750
6.	Orthoclase gneiss, with several bands of garnetiferous gneiss and quartzite, and with much coarse-grained porphyroid gneiss	3,500
7.	Crystalline limestone of Great Beaver Lake and Green Lake, including two bands of interstratified garnetiferous rock and hornblendic orthoclase gneiss	2,500
8.	Orthoclase gneiss	4,000
9.	Crystalline limestone of Trembling Lake	1,500
10.	Orthoclase gneiss composing Trembling Mountain, lower limit not ascertained, thickness probably exceeds	5,000
		32,250

The base of the series was thus a great body of orthoclase gneiss —the Trembling Mountain gneiss—above which were four belts of limestone, certain of them of great thickness, alternating with orthoclase gneiss; the whole succeeded by a great development of anorthosite.

The alternation of limestone with gneiss was considered by Logan as proving that the whole series represented a great body of highly altered sediments, the oldest sediments recognizable in the earth's history. The foliation exhibited by the bodies of orthoclase gneiss

lying between and below the limestones, as well as that exhibited by the anorthosite, was regarded as the survival of an almost obliterated bedding, and this foliation, as has been mentioned, extended down to the very base of the whole series. The existence of this great thickness of anorthosite superimposed upon, and, therefore, presumably younger than the orthoclase gneiss, was in a brilliant paper by Sterry Hunt, explained as due to a succession of chemical reactions which must necessarily have been developed during the cooling of the earth from whose primeval ocean the whole series was supposed to have been deposited in the order of their succession.[1]

Since Logan's time, however, the great advance in our knowledge of petrography has thrown a flood of light upon the nature of the crystalline schists and a study of the area lying immediately to the east of that mapped by Logan made it evident that Logan's conclusions must be in part revised.

The Fundamental Gneiss, in the first place, is found to be a great body of uniform, fine-grained, foliated granite, showing under the microscope excellent protoclastic structure. It is clearly an igneous intrusion in which foliation has been developed by movement under pressure. The suggestion of stratification which it presents owing to its foliation, is enhanced by the presence in it of occasional lenticular bands of dark amphibolite. These, of course, lie parallel to the foliation, that is, to the direction of movement in the rock, but are evidently inclusions of the overlying rock which was intruded by the granite. The thickness of this fundamental gneiss (5,000 feet), considered even by Logan to be wholly conjectural, must therefore be deducted from the total thickness given in the above section.

The anorthosite, when traced to the east, is also proved beyond doubt to consist of a great body of igneous rock having a pronounced foliation, especially near its margin, and which cuts off the limestone bands where it meets them. Its thickness (10,000 feet), which was also considered by Logan to be wholly conjectural, must also be deducted.

It is furthermore certain, as the result of recent work, that the gneisses associated with the limestones are in part of igneous origin

[1] "The Chemistry of Metamorphic Rocks," *Chemical Geological Essays*, Boston, 1875.

and in part represent highly altered sediments. It is impossible in all cases to distinguish these two classes of rocks, but the distinction can in many cases be made with certainty.

The sedimentary gneisses (paragneiss) are fine in grain and usually occur intimately associated or interstratified with the limestones and quartzites, and very frequently weather to a rusty color. From the thickness of the limestone bands given above, there must be deducted that of the igneous gneiss included in or associated with them.

It is also by no means certain that the four limestones mapped by Logan are all separate bands, seeing that the intervening belts of gneiss, being largely igneous in origin, can no longer be regarded as representing separate stratigraphical elements, but may be intrusions separating portions of one and the same body of limestone. Whether or not this latter presumption represents the truth, can, however, only be determined by a complete re-examination of Logan's work in this area. In the meantime it is certain that the highest and lowest members of his series are bodies of intrusive rock in which a foliation has been induced by pressure. The deduction of these reduces the thickness of the series by 15,000 feet, and that a much greater reduction than this must be made if the true thickness of the sedimentary portion of the series is to be ascertained, is evident from what has been already stated.

In his map of this area, Logan separated the anorthosite and designated it as Upper Laurentian, while the other rocks of the series were classed as Lower Laurentian or Grenville series. In after years the lowest gneiss came to be known as the Fundamental Gneiss or Ottawa Gneiss, while the name "Grenville series" was restricted to the limestone-bearing portion of Logan's Laurentian.

This work of Logan, while in many respects imperfect, was nevertheless a first approximation to a true knowledge of the Laurentian and served as an excellent basis for the work of subsequent investigators.

Logan subsequently found in eastern Ontario a series of rocks which he considered in all probability to represent the Grenville series in a less altered form, and to these he gave the name of the "Hastings series."

THE HALIBURTON-BANCROFT AREA IN EASTERN ONTARIO

The Haliburton-Bancroft area in eastern Ontario, the mapping of which has just been completed, occupies a position on the margin of the protaxis corresponding to that of the "Original Laurentian Area" but is some 175 miles further west. It is very similar in petrographical character to Logan's area but presents a somewhat greater variety of rock types, the distribution of twenty different rock types being represented on the Bancroft sheet accompanying the report on the area in question.

The Grenville series in this area presents a diversified series of undoubted stratified rocks among which limestones preponderate, but they rest upon and are invaded by an enormous body of gneissic granite.

To the southeast, toward the margin of the Paleozoic cover, the sedimentary series is largely developed and is comparatively free from igneous intrusions. Toward the northwest, however, the granite, in ever increasing amount, arches up the sedimentary series and wells up through it, in places disintegrating it into a breccia composed of shreds and patches of the invaded rock scattered through the invading granite, until eventually connected areas of the sedimentary series disappear entirely and over hundreds of square miles the granite and granite gneiss alone are seen, holding, however, in almost every exposure, inclusions which represent the last scattered remnants of the invaded rocks.

The type of structure presented by the invading granite is that of a bathylith.

The limestones.—The limestones in this Laurentian district are very thick and underlie a large part of the area. In their more altered form they exactly resemble those described by Logan in the areas examined by him, but to the southeast of the Bancroft sheet, where the invading granite is less abundant and the alteration of the invaded strata is correspondingly less pronounced, the limestones appear in less-altered forms and eventually pass into fine-grained, grayish-blue varieties in which the bedding is perfectly preserved and concerning whose truly sedimentary character there can be absolutely no doubt. The gradual transition of the comparatively unaltered bluish limestone into the coarsely crystalline white marble takes place by the develop-

ment in the former of little strings or irregular patches of coarsely crystalline white calcite, usually following the bedding planes. These become larger and more numerous on going north in the area toward the granite intrusions, until eventually the whole are transformed into great bodies of white marble. Here and there through this marble, where it is very thick, small remnants of the original blue limestone can occasionally be found.

Enormous bodies of nearly pure limestone or marble occur in many parts of the area, but elsewhere it becomes impure, owing to the presence of numerous scales and granules of various silicates distributed through it, or owing to the appearance of numerous little bands of silicates representing impurities in the original limestones, which, under the influence of metamorphism, develop into gneisses and amphibolites of various kinds. Where these little gneiss or amphibolite bands become increasingly abundant, the limestone passes over into paragneiss or into some one of the varieties of amphibolite.

The limestone in what may be called its usual development, that is, in its highly crystalline form, is a white, cream-colored, or pinkish marble, and is generally very coarse in grain. The little grains or scales of foreign minerals scattered through it are usually arranged so as to indicate the lines of the original bedding. No less than thirty-seven species of these minerals have been found in the limestones in this area, of which phlogopite, malacolite, serpentine, scapolite, graphite, and pyrite are the most common.

That the limestone has in many places been subjected to great movements can be distinctly seen on the face of any high cliffs or where other large surfaces of the limestone are exposed. Here the interstratified bands of gneiss or amphibolite can be seen winding to and fro over the exposed surface, often folded back upon themselves or broken into fragments which have become widely separated from one another by the movements, the more plastic limestone having flowed in between them, the rock often in this way taking on the appearance of a coarse conglomerate.

The quartzites.—Quartzite is not common in this area. Where it occurs it is found interstratified with the crystalline limestones and rusty weathering paragneisses. It is well foliated and rather fine

in grain, sometimes containing a certain amount of feldspar as an accessory constituent, and elsewhere containing some pale-green pyroxene, which is evidently derived from the alteration of a certain amount of calcareous matter originally present.

Under the microscope the quartz of these quartzites is seen to have the form of elongated grains arranged in the direction of the foliation and showing very marked strain shadows, sometimes passing into a distinct cataclastic structure. There is every reason to believe that these quartzites represent, in most cases at least, altered sandy sediments.

The gneisses of sedimentary origin (*paragneiss*).—These gneisses differ distinctly in appearance from the foliated granite gneisses already referred to, and which constitute the bathylithic intrusions. They are fine in grain and show no protoclastic or cataclastic structure, the original material having been completely recrystallized. They have an allotriomorphic structure, with a tendency of certain of the constituent minerals to elongate themselves in the direction of the original bedding. While quartz, feldspar, and biotite are among the constituents present, the mica is usually more abundant than in the granite gneisses, and, in addition, garnet, sillimanite, graphite, and pyrite are very frequently present, the last giving rise to a prevailingly rusty color on the weathered surface. These gneisses occur in the form of well-defined beds and are usually found intimately associated with the limestones. They resemble in many respects the hornstones which are found in granite contact zones, but are rather more coarsely crystalline than is usual in this class of rocks.

These gneisses, while presenting a general similarity in appearance, show a considerable diversity in composition and are evidently derived from the recrystallization of sediments which varied considerably in character. The two following analyses show extreme cases of this variation.

No. I occurs interstratified with beds of white garnetiferous quartzite at St. Jean de Matha in the Laurentian district to the north of Montreal. It is composed of quartz, orthoclase, garnet (in large amount), and sillimanite, with smaller amounts of rutile, biotite, pyrite, graphite, and serpentine, the latter mineral resulting from the

alteration of some constituent which has now entirely disappeared. As will be seen, the rock has the composition of an ordinary clay slate, possessing the characteristic high content of alumina with a low percentage of alkalis and a great preponderance of magnesia over lime, which is characteristic of these rocks.[1]

	No. I	No. II
SiO_2	61.96	79.70
TiO_2	1.66	.30
Al_2O_3	19.73	8.29
Fe_2O_3		.41
FeO	4.60	1.17
FeS_2	4.33	Not det.
MnO	Trace	.03
CaO	.35	.67
BaO		.08
MgO	1.81	.76
Na_2O	.79	1.43
K_2O	2.50	4.11
P_2O_5		.04
Graphite	Not det.	3.00
Water	1.82	.70
	99.55	100.69

No. II is from the township of Stanhope in the Haliburton area and is distinctly different in composition. If the "Mode" or percentage mineral composition of this rock be calculated, it is found to be as follows:

	PER CENT.
Quartz	55.20
Orthoclase	18.94
Oligoclase	14.46
Biotite	3.45
Muscovite	3.50
Rutile	.30
Apatite	.09
Calcite	.28
Graphite	3.00
Water	.54
	99.76

[1] See F. D. Adams, "A Further Contribution to our Knowledge of th tian," *American Journal of Science*, July, 1895.

If the quantitative classification be adopted, this rock would find its place as a Tehamose, a division which includes many granites and liparites, and, so far as its chemical composition is concerned, might be of igneous origin, although few liparites contain so high a percentage of silica. Its mode of occurrence and structure, however, indicate that it is of sedimentary origin and it evidently results from the recrystallization of some arkose-like material derived from the disintegration of granite rocks.

These sedimentary gneisses (paragneisses) clearly represent deposits of argillaceous, or in some cases arenaceous sediment, often more or less calcareous, which were laid down in the same sea in which the limestones were accumulated.

In a extreme southern portion of the Bancroft area there is a considerable development of clay stones (often siliceous or calcareous) which probably represent these gneisses in a less altered form, but which probably, at the same time, hold a considerable admixture of volcanic material.

The amphibolites.—Intimately associated with these sedimentary gneisses and the limestones on one hand, and with the gabbros and diorites on the other, are other rocks which are grouped under the name of amphibolite. While many varieties of these rocks occur in the area, differing considerably from one another in appearance, they have as common characteristics a dark color and a basic composition. Quartz, which is one of the commonest constituents in the gneisses, is absent, or is present only in very small amount, while hornblende and feldspar, the latter chiefly plagioclase, are the chief constituents of the rock. Pyroxene or biotite often replaces the hornblende in part. In places the sedimentary gneisses fade away into occurrence of amphibolite when traced along the strike. Masses of amphibolite also, as has been mentioned, abound as inclusions throughout the granite of the bathyliths.

These amphibolites, furthermore, are not peculiar to this area but occur abundantly everywhere in the Laurentian. They have always proved to be one of the chief difficulties in the way of a correct understanding of the geology of this system, seeing that it has been impossible to do more than indulge in conjectures concerning their origin. The same difficulty has been met with in the case of these and allied

rocks occurring elsewhere, as for instance the trap granulites of the Saxon Granulitgebirge or the amphibolites of the crystalline complex of certain portions of the Alps, whose origin remains in doubt while that of the rocks with which they are associated has been definitely determined.

As the result of a very careful examination, it has been possible to prove conclusively that in this area the amphibolites have originated in three entirely different ways, the resulting rocks, although of such diverse origin, often being identical in appearance and composition. This remarkable convergence of type, whereby rocks of widely different origin come to assume identity of character, explains the difficulty which has been experienced up to the present time in arriving at a satisfactory conclusion concerning their genetic relations. These three ways are: (*a*) By the metamorphism and recrystallization of impure calcareous sediments; (*b*) By the alteration of basic dykes and similar igneous intrusions; and (*c*) By the contact action of the granite bathyliths on the limestones through which they cut. The question of the origin of these amphibolites is discussed elsewhere.[1]

THICKNESS OF THE GRENVILLE SERIES IN THE HALIBURTON-BANCROFT AREA

While in most parts of this area the Grenville series is so torn to pieces by igneous intrusions that no development of it can be found sufficiently continuous to enable its thickness to be measured, there are in certain parts of the area developments where these intrusions are distinctly subordinate and in which such measurements can be made with at least the same degree of accuracy as in the case of any other pre-Cambrian series.

One such district is that where the four townships of Anstruther, Burleigh, Chandos, and Methuen meet. Here a well-defined synclinal is succeeded to the east by an anticlinal, and the following succession of strata, which however does not represent a complete section through the Grenville series of this area, is expressed in descending order (Burleigh-Chandos section).

[1] *Journal of Geology*, Vol. XVII, No. 1.

	FEET
Limestone of Jack's Lake	6,770
Rusty weathering gneiss with associated amphibolites, crossing Lots 29–35 of Range I of Anstruther	5,754
Limestone with bands of sedimentary ("feather") amphibolite north of Loon Lake	3,060
Amphibolite north of Loon Lake	2,190
Limestone at Duck Lake (nearly flat, only surface exposed), say	50
	17,824

Another line of section along which the Grenville series is excellently exposed and along which measurements with a view to determining the thickness of the series may be made, is furnished by the Hastings road. This is one of the most striking sections of strata of pre-Cambrian Age to be found anywhere in the world. The road was constructed many years ago by the government for the purpose of enabling settlers to penetrate into what was then a very wild, remote, and inaccessible portion of the Dominion. A line was drawn on a map and orders were given to lay out the road along the line in question. The result was that a long road was constructed, starting from the rear line of the township of Madoc, running in an almost straight line to the Madawaska River, holding throughout almost its entire course a direction of N. 20° W. This road, which traverses the whole width of the Bancroft sheet and almost the whole width of the area embraced by the Haliburton sheet, fortunately for students of geology, runs about at right angles to the strike of the country rock, and throughout the whole southern portion of its course traverses the Grenville series, affording excellent exposures. The selection of this course for the road was, however, correspondingly unfortunate for the settlers who took up land in the district, since the road holds its course quite irrespective of hill or valley, and in its course passes directly across several great gabbro intrusions which give rise to an exceedingly rough type of country, and which might easily have been avoided had a slightly different line been adopted.

As will be seen by consulting the Bancroft sheet of the Ontario series of maps now being issued by the Geological Survey of Canada, throughout a distance of 25.3 miles from lot 30 of the township of Madoc to 60 in the township of Faraday, except where it crosses the gabbro intrusions above mentioned, whose width has been

deducted in arriving at the measurement just given, the Hastings road passes continuously across the limestone and amphibolites of the Grenville series, and throughout this whole distance crosses these latter practically at right angles to their strike.

Furthermore, throughout the whole distance these strata dip in a southerly direction at high angles. Here and there, at long intervals and for a few yards, a reversed or northerly dip can be observed, but this is merely local owing to a minor undulation in the strata which has no stratigraphical significance.

The angle of dip naturally varies somewhat from place to place, but the average dip may be taken as 45°. This is a minimum estimate, the average dip along the whole section being in all probability somewhat higher. Taking this value we obtain the following result:

Apparent thickness of the Grenville series along the line of section
=25.3 miles=133,584 feet.
True thickness of the Grenville series along this line of section
=17.88 miles=94,406 feet.

It must be noted that the series is one which along the whole length of this section presents a continuous alternation of beds of varying character, so that it is not a foliation but a true bedding that is observed and measured.

It is, moreover, to be noted that while this thickness is so great as to suggest reduplication of some sort by isoclinal folding or by faulting, there is no stratigraphical evidence that such reduplication exists, and a fact of very great importance to be noted is that if there be such reduplication, the basement upon which the series was deposited is nowhere brought up along the whole line of section as would undoubtedly be the case unless the series reduplicated by folding was of enormous thickness.

For purposes of comparison the estimated thicknesses of some of the other great developments of pre-Cambrian rocks in North America are presented on a later page.

In all these districts there is, as in that at present under consideration, a possible error due to partial repetition by folding.

In the Grenville series, as has been stated, limestones predominate,

and these sections afford data for determining the relative proportion of limestone present.

In the Burleigh-Chandos section given above the Jack Lake limestone is essentially a body of pure limestone, while the Loon Lake limestone band may be estimated to be about half limestone. This gives a thickness of about 8,350 feet of limestone in that section out of a total of 17,824 feet, that is to say, 46.8 per cent. of pure limestone.

The estimated thicknesses above referred to are as follows:

	FEET
Huronian-Marquette Iron Range, Michigan, U. S. A.[1]	12,590
Huronian-Menominee Iron Range, Michigan, U. S. A.[2]	4,650 to 6,400
Huronian-Penokee Iron Range, Michigan, U. S. A.[3]	13,950
Huronian-Mesabi Iron Range, Minnesota, U. S. A.[4]	6,800 to 8,800
Huronian & Keewatin-Vermilion Iron Range, Minnesota, U. S. A.[5]	13,350 to 15,550
Couchiching series in Rainy Lake District, Ontario, Canada[6]	23,760 to 28,754

With these may be compared:

Belt Formation in Montana, U. S. A.[7]	12,000
Pre-Cambrian of Lewis & Livingstone Ranges, Montana, U. S. A.[8]	9,900 to 10,700

[1] C. R. Van Hise, and W. S. Bayley, "The Marquette Iron-bearing District of Michigan" (Monograph), *U. S. Geol. Survey*, 1897.

[2] W. S. Bayley, "The Menominee Iron-bearing District of Michigan" (Monograph), *U. S. Geol. Survey*, 1904.

[3] R. S. Irving and C. R. Van Hise, "The Penokee Iron-bearing Series of Northern Wisconsin and Michigan" (Monograph), *U. S. Geol. Survey*, 1892. This thickness is arrived at by adding to the aggregate thickness of 1,950 ft., given for cherty limestone, quartz slate, and iron-bearing member an additional thickness of 12,000 ft. for the upper slate member, which thickness is that of the Hanbury slate, which in the Menominee Range is its equivalent.

[4] C. K. Leith, "The Mesabi Iron-bearing District of Minnesota" (Monograph), *U. S. Geol. Survey*, 1903.

[5] J. M. Clements, "The Vermilion Iron-bearing District of Minnesota" (Monograph), *U. S. Geol. Survey*, 1903.

[6] A. C. Lawson, "Annual Report of Progress," *Geol. Survey of Canada*, 1885, p. 108 c. c.

[7] "Pre-Cambrian Fossiliferous Formations," *Bull. Geol. Soc. Am.*, Vol. X, pp. 201–15.

[8] Bailey Willis, "Stratigraphy and Structure of Lewis and Livingstone Ranges, Montana," *Bull. Geol. Soc. Am.*, Vol. XIII, pp. 316–24.

In the section along the line of the Hastings road, it is estimated that the "blue limestone" and the "limestone and amphibolite," which represent the calcareous part of the series, contain about two-thirds of their thickness of pure limestone. This would give a thickness of 50,286 feet of pure limestone out of a total thickness of 94,406 feet, equal to 53.3 per cent. This latter section, being a much longer one, probably represents more nearly the average proportion of limestone in the Grenville series as developed in this area, which in its turn affords a representative area of the series as it occurs in Canada, so that it may be stated that the Grenville series, as a whole, contains rather more than one-half its thickness of pure limestone. The thickest development of limestone in any occurrence of the Huronian in America is the Randville dolomite in the Menominee Range, which attains a thickness of 1,500 feet. In the Belt Formation and in the series of pre-Cambrian rocks in the Lewis and Livingstone Ranges, there is a thickness of limestone amounting to 4,400 and 5,400 feet respectively.

As will be seen, the thickness of limestone in the Grenville series is much greater than in any of these.

It may be safely stated that the Grenville series presents by far the thickest development of pre-Cambrian limestones in North America, and that it presents at the same time one of the thickest, if not the thickest, series of pre-Cambrian rocks on this continent.

AREAL EXTENT OF THE GRENVILLE SERIES

Not only has the Grenville series a great thickness, but it has a very wide areal distribution. It is exposed along the southern border of the protaxis from the Georgian Bay eastward to a point considerably beyond the St. Maurice River, which flows into the St. Lawrence at the town of Three Rivers. It extends to the northward in the Laurentian Highlands at least as far as the latitude of Cobalt, although not reaching so far west as this point, which lies in a Keewatin and Huronian district. To the southeast it is stated by Professor H. P. Cushing to be exposed at intervals over the whole Adirondack area, while to the southwest deep borings under the city of Toronto have brought up, from beneath the Paleozoic, cores of a white crystalline limestone which evidently belongs to the same series. The area thus

outlined embraces 83,000 square miles. In areal extent, therefore, it can be compared only with certain of the greatest developments of the Paleozoic limestones in North America as for instance the Knox Dolomite of the Southern Appalachians. Over this area of 83,000 square miles, the Grenville series is not, of course, now continuously exposed. It is penetrated in many places by great intrusions of granite and anorthosite. This is especially true of the Adirondack Mountains in which these intrusives are especially numerous. This area, however, is one which was originally undoubtedly covered by a continuous development of the Grenville series.

In all probability, however, the areal distribution of the Grenville series is much greater than this. In many parts of the Laurentian Highlands far to the north of the limit here taken as the boundary of the Grenville series, areas of white crystalline limestone and associated rocks are found which are identical in character with that of this series. Enormous developments of such limestones, identical in all respects with the Grenville series, are, for instance, found about the shores of Hudson Straits. Whether these northern limestones belong to the same series is however not at present known with certainty. Definite information on this point may be obtained as our knowledge of this great northern country becomes more complete. It is furthermore very highly probable, as the Grenville series along the southern margin of the protaxis everywhere disappears to the south beneath the Paleozoic cover, that in this direction it originally had a very much greater extent than that over which it is at present exposed. In this connection it is important to note that the pre-Cambrian limestone series of the Highlands of New Jersey, which has recently been studied by Bayley, has by him been correlated with the Grenville series.[1] The facts, however, in our possession at present show that the Grenville series is one of the greatest limestone series in North America and that it presents, as has been mentioned, the greatest development of limestone known in the pre-Cambrian.

CORRELATION OF THE GRENVILLE SERIES

In connection with the Grenville series one other question presents itself, namely, whether this great series represents a continuous suc-

[1] "Preliminary Account of the Geology of the Highlands of New Jersey," *Science*, May 8, 1908, p. 722.

cession of strata or whether in it there may be two series of identical petrographical character, intimately associated, and which have been subjected to the same intense and widespread metamorphism. The information hitherto accumulated and bearing on the question may be briefly stated. In the report upon the Haliburton-Bancroft area, by Dr. Barlow and the writer, to which reference has already been made, the occurrence of conglomerates at a few separated points in the southern portion of the area is described and the conclusion is reached that certain of these are probably of epiclastic origin and indicate an unconformity in the series. If two series be present, however, the intense metamorphism and folding has rendered it impossible to delimit them in the area embraced by the report in question. When the international committee representing the geological surveys of the United States and Canada (appointed for the purpose of effecting a correlation of the pre-Cambrian rocks of the Adirondack Mountains, the "Original Laurentian Area" and Eastern Ontario) visited the Madoc district, which lies to the south of the Haliburton-Bancroft area, they examined a conglomerate near the town of Madoc and concluded that it probably represented a break in the pre-Cambrian sedimentary limestone series as there developed. Miller and Knight, who visited the district in the autumn of last year, stated in a short paper which appeared in the *Report of the Ontario Bureau of Mines* for 1907 (p. 202), and which was afterward read before the American Geological Society, that "a few days in the field has made the relationship of the sedimentary series quite plain, and the view that the Grenville and Hastings series constitute one series, the former being a more highly altered phase of the latter, is no longer tenable." A careful study extending over many months, however, shows that Logan was quite right and that the comparatively unaltered strata of what he mapped as the Hastings series pass over imperceptibly into the typical Grenville series. What the committee saw, and Messrs. Miller and Knight have substantiated, is that within this unaltered "Hastings series" of Logan, as also probably in the more altered "Grenville" phase of the same rocks, there are two series which are petrographically identical. These series, when worked out, should be distinguished by specific names, as Upper and Lower Grenville, or one may be termed the "Madoc series." Logan's "Hast-

ings series" is the less altered phase of both and to employ it now, to designate either, is to use it in a new sense differing from that of Logan and thereby introduce confusion in the nomenclature. Messrs. Miller and Knight conjecturally set down the lower of these two series, with its enormous body of limestone and other sediments, as Keewatin and as the equivalent to the Keewatin iron formation of Lake Superior, correlating the upper series with the Huronian.

Van Hise in his recent "Presidential Address,"[1] however, very properly declines to accept this view until some evidence has been adduced in favor of such a supposition.

In fact, if conjecture must be indulged in, it is much more reasonable to correlate the whole series, being, as it is, essentially a great sedimentary limestone series, with the Huronian, owing to the fact that as we come east in the Huronian developments of the iron ranges of Lake Superior, limestones become more abundant. The thickest and greatest bodies of limestone in the whole western pre-Cambrian are those of the Menominee Range. It may easily be that still further east the Huronian becomes still more highly calcareous and takes on essentially a limestone facies, while the Keewatin has essentially a pyroclastic development.

But it must be borne in mind that so far as is known at present, the Grenville series may be a distinct entity, separate from either and differing in age from both. This can only be ascertained by a further detailed examination of the intervening areas.

Whatever may be the result of future studies—whether it be established that the Grenville series is to be correlated with members of the pre-Cambrian development in the west or whether it proves to be a series differing in age from any of these—it remains the greatest development of limestone known in the pre-Cambrian of North America and one of the greatest limestone developments of any age.

[1] *Bull. Geol. Soc. of America*, March 30, 1908.

A STUDY OF THE DAMAGE TO BRIDGES DURING EARTHQUAKES.[1]

WM. HERBERT HOBBS

To the study of the damage sustained by buildings during earthquakes a vast amount of attention has been devoted, while other structures, better suited to reveal the nature of the disturbance have hardly been examined at all from the scientific standpoint. This is in part to be explained because the damage has been supposed to result wholly from elastic waves, but in part it has been determined by the obvious necessity of safeguarding the lives of the inmates of the buildings. Adopting the newer viewpoint that the vibrations felt at the surface of the earth are genetically at least a secondary rather than a primary cause of the disturbance, our attention must be turned in a different direction. In place of high structures we must study low ones, and from inspecting damage at isolated points we must note the distribution of the damage along complete sections crossing the affected district. Buildings thus give place in importance to railways, pipe lines, and to metal cables, and in fact to any *continuous* structures of fairly uniform strength and rigidity over long distances. Such structures are suited to register either tensional or compressional stresses.

Railway tracks, now the most generally available of these structures, preserve a record of tension in the tearing out of fish-plates and separation of rail ends, and of compression in the jamming of the joints and the buckling or kinking of the metals. The first and most striking result of observation of the damage to such structures, is the common occurrence of distinctly local maxima of deformation (see Fig. 1, *C* and *D*). The zones of deformation are not always, however, so narrow as in these instances, but may be betrayed by a sinuous course of the rails extending over a considerable fraction of a mile (see Fig. 1, *A*).

[1] A paper read before the American Association for the Advancement of Science at the Chicago Meeting, December, 1907.

There is a type of structure whose sensitiveness for recording earth movements seems never to have been given its due weight, for we look in vain for any grouping of the evidence from damage sustained

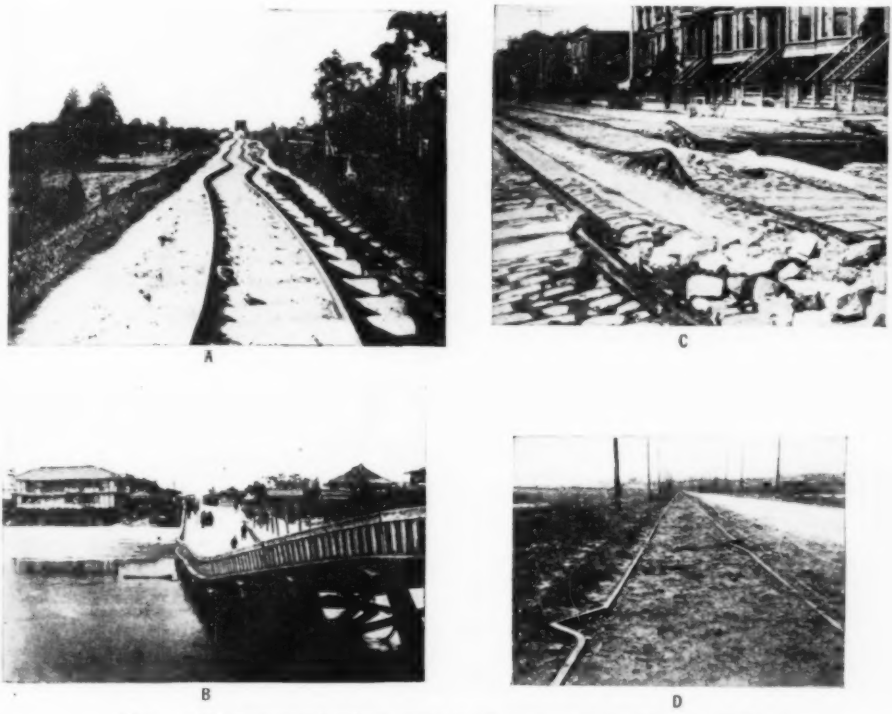


FIG. 1.—(*A*) Compressed railway tracks in the approach to the Kisogawa Railway bridge after the Japanese earthquake of 1891 (after Milne and Burton). (*B*) Biwajima Road bridge thrown into a serpentine form during the Japanese earthquake of 1891 (after Milne and Burton). (*C*) Car tracks which have sustained a sharp local compression along an oblique intersecting line. California earthquake of 1906 (after H. W. Fairbanks). (*D*) Electric railway tracks near San Francisco, showing a sharp local compression along an oblique intersecting line. California earthquake of 1906 (after Moran).

by bridges at the time of earthquakes. The writer has recently noted in a brief statement the rather common observation that the abut-

ments of bridges have approached each other during earthquakes,[1] and it is now proposed to assemble the evidence on which the statement was based and to suggest an explanation of the phenomenon. It is to the descriptions of destructive earthquakes of comparatively recent date and in countries of considerable industrial development that we must go for our evidence, since it is the bridges of better construction, and the railroad bridges especially, which furnish the most satisfactory evidence. Data are available from the Charleston earthquake of 1886, the Japanese earthquakes of 1891 and 1894, the Indian earthquake of 1897, the California earthquake of 1906, the Kingston earthquake of 1907, and probably others.

THE "CHARLESTON" EARTHQUAKE OF AUGUST 31, 1886

A typical illustration is here furnished by the Charleston and Savannah Railway bridge over the Ashley River after the earthquake of August 31, 1886.[2] The diagrammatic sketch after Dutton, which is reproduced here in Fig. 2, is especially valuable, since it well illustrates a characteristic distortion of the abutments of bridges observed after a destructive earthquake. Of this bridge Dutton says:

FIG. 2.—Bridge over the Ashley River, South Carolina, as it appeared after the earthquake of August 31, 1886 (after Dutton).

> The approach to the bridge is by a long embankment, traversing a marshy flat with an ascending grade, giving place near the bridge to a high trestle. An embankment and trestle lead to the bridge from the opposite side. The draw-bridge was closely jammed by the earthquake, the immediate cause being the sliding or creeping of both river banks toward the center of the stream, carrying the trestle with them. West of the river the joints of the rails were torn open by tension produced in this sliding motion. (P. 304.)

The only other railroad bridge within the so-called "epicentral tract" of this earthquake was on the same line of railway near Rantowles Station:

[1] *Earthquakes, An Introduction to Seismic Geology* (D. Appleton & Co.), 1907, p. 230.

[2] C. E. Dutton, "The Charleston Earthquake," *9th Annual Report*, U. S. Geol. Survey, p. 231.

The piling, which affords no indication of relative movement from inclosing earth, has dragged attached bents from vertical positions and jerked the superstructure from opposite sides to the center line with violence, wrecking rails, bulging up stringers, forcing up the caps of bents which were mortised with four-inch tenons, and in general affording liberal indications of shortening of the distance separating banks. (Pp. 304, 305.)

Of culverts and trestles there were many which received serious damage at the time of this earthquake, and all appear to have been deformed by a longitudinal compression.[1]

THE MINO-OWARI EARTHQUAKE OF OCTOBER 28, 1891[2]

This earthquake has furnished some of the best illustrations anywhere available of the nature of damage to bridges during a destructive earthquake.

The Biwajima-Bashi, a wide wooden carriage bridge across the Schonaigawa, was completely wrecked. It lies in the bed of the river in a curious serpent-like twisted form. The river is very low, and the continuity of the bridge was nowhere actually broken, so it was possible to walk across, though the feat was not an easy one on account of the angle at which the footway was canted. (See Fig. 1, *B*.)

A brick railway bridge near the Biwajima River presented a singular appearance. The abutments which ordinarily had been perpendicular, had apparently been pushed backward to the right and left, and the arch which they ordinarily supported lay in two huge quadrant shaped masses blocking up the roadway between them. (See Fig. 3, *D*.)

Speaking of the Kisogawa bridge, Milne and Burton say:

a) *Approaches.*—A more important feature is, however, the serpent-like bending of the line. Not only have the metals been deflected, but the embankment has suffered a parallel deformation. It seems as if the country here—and similar appearances are presented at other places—had been subjected to a permanent longitudinal compression. At each of these bends, although not shown in the present picture, to the right and left of the line, there is generally a slight compression in the general contour of the country which possibly may mark the line of an ancient watercourse, in which we may imagine that the materials are softer than elsewhere. (See Fig. 1, *A*.)

b) *Bridge.*—The lateral shifting of the foundations by which the distances between the piers have been reduced, has been the result of a permanent compression which, had the bridge been represented by a line across the river bed, would have been contorted into one or more snake-like bends. (See Fig. 3, *A*.)

[1] *Loc. cit.*, pp 286, 290.

[2] John Milne and W. K. Burton, *The Great Earthquake in Japan*, 1891, Yokohama, (Lane, Crawford & Co., 1892), 2d ed.

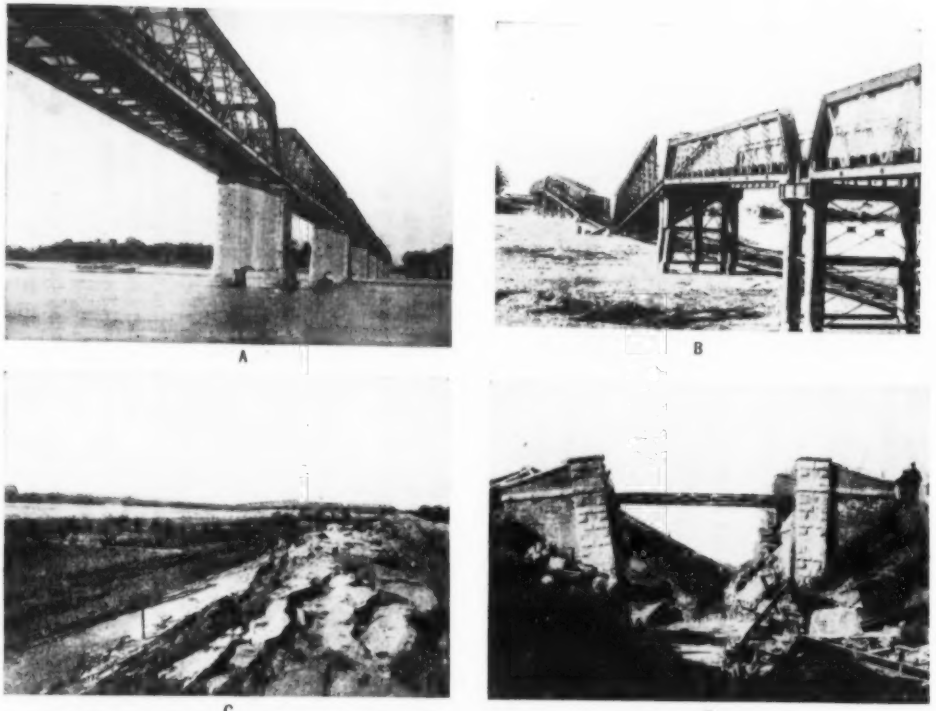


FIG. 3.—Damage sustained by bridges during the Japanese earthquake of 1891 (after Milne and Burton). (*A*) Kisogawa Railway bridge with fractured piers. (*B*) Nagaragawa Railway bridge fallen in part into the river bed but still continuous. (*C*) Nagaragawa bridge (in distance) with fissured river banks in foreground. (*D*) Biwajima Railway bridge showing distorted abutments and fallen arch.

Speaking of a bridge near the Kiso River and also near the great Kisogawa bridge just referred to, the authors state that this bridge consists of two spans of 70-foot plate girders, and add:

> The end walls or abutments are cut through horizontally, and the solid brick "well" which supported the central pier between the spans is broken across like a stick. The upper portion of the well has moved three feet sideways on the line of fracture.
>
> From the photograph it will be seen that while the south abutment is broken through horizontally, the side walls are cracked diagonally.
>
> At the end of the crack where it rises from the ground it was discovered, on taking the brick work down for reconstruction that the earthquake had thrown the foundations of each wing wall 10 inches away from the well formation of the abutment which originally was touching the foundations. (See Fig. 5, *A*.)

Thus in this case, also, it appears that the abutments showed evidences of the shortening of the distance between them in their tilting back from the river.

Probably the most interesting and instructive example yet furnished of the deformation of bridges during earthquakes is that of the railway bridge over the Nagara River (See Fig. 3, *B* and *C*).

> The main part of the bridge consists of five independent thrust girders of wide span. The piers at the two ends of one of these girders are completely wrecked and the girders have fallen bodily into the bed of the river. The piers on either side of the two mentioned are partly wrecked, and the girders between them and the first-mentioned girders rest, each with one end in the river bed, the other on the top of the partly destroyed pier. The remaining girders are in their original positions or nearly so.
>
> It will again be observed that the portion of the bridge which has fallen relative to the part which remains standing, has been thrown some distance out of a straight line.
>
> Examination has shown that this displacement is not simply a displacement of the upper-work of the bridge, but the ground with the screw-pile foundations has been shifted a distance of several feet up the stream.
>
> The embanked approach to the Nagaragawa bridge has been thrown into a regular series of undulations of such extent that, looking along the line eastward from the eastern abutment, the appearance is almost that of looking along a switch-back railway.

It will not fail of observation that the bridge spans, though fallen in some instances from their foundations, and further shifted some distance up stream, approximate to curved sections, in both horizontal and vertical planes, yet maintain their continuity across the river

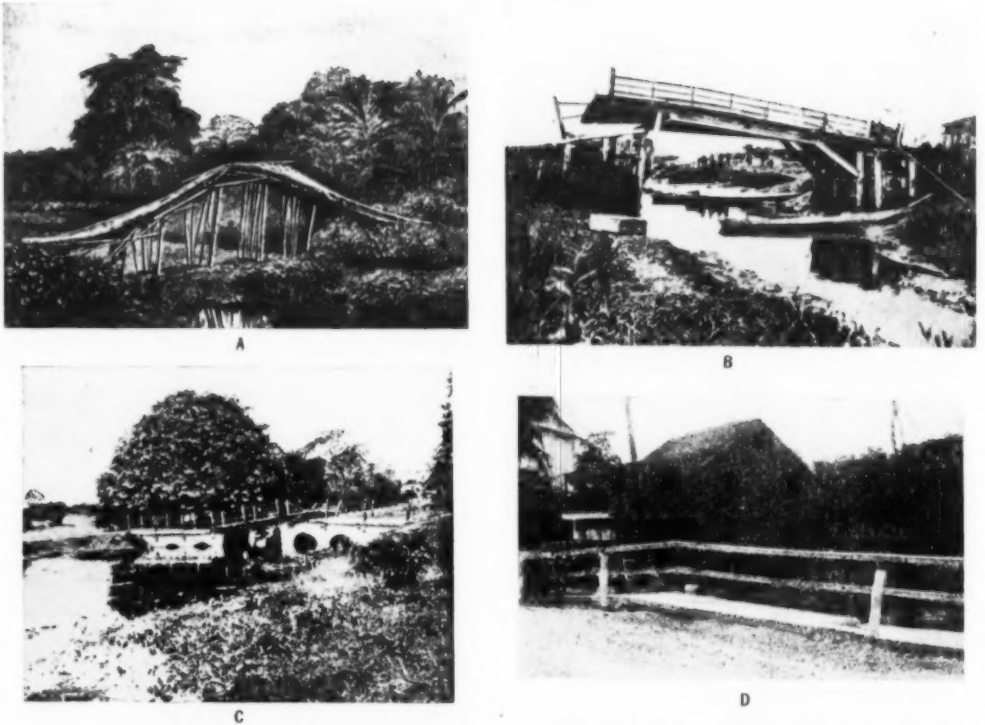


FIG. 4.—(*A*) Bridge over a stream at Rangpur after the Assam earthquake of 1897. The center of the stream channel has been raised (after R. D. Oldham). (*B*) A rustic bridge after the Schonai (Japan) earthquake of 1894, with its girder pushed up over the abutment (after Kikuchi). (*C*) Bridge over a canal at Rangpur after the Assam earthquake of 1897. Girder pushed up over abutment (after R. D. Oldham). (*D*) Bridge near Kingston damaged by approach of abutments during the Jamaica earthquake of 1907 (after Fuller).

from bank to bank. The narrowing of the distance between banks which is thus indicated is considerable. This is shown in Fig. 3, *B* and *C*.

EARTHQUAKE OF SCHONAI, JAPAN, IN 1894

An interesting illustration of the approach of the abutments of a rustic bridge during the Schonai earthquake is seen in Fig. 4, *B*. In this case the girder has slid up over one of the abutments so as to allow the latter to move toward the stream.[1]

GREAT ASSAM EARTHQUAKE OF JUNE 12, 1897[2]

Next to the Mino-Owari earthquake this great disturbance has furnished perhaps the largest number of examples of wrecked bridges. These will be discussed, therefore, in some detail:

Bridge on Grand Trunk Railroad west of Gauhati:

At the western end of the Gauhati Bazar is a bridge of three girders carrying the Grand Trunk Road over a small stream, which here joins the Brahmaputra. The original length of the bridge, as measured along the hand rail, was 99 feet, 4 inches, while the present length, between the same points, is 97 feet, 10 inches. The bridge has therefore been shortened 18 inches. This has been caused by fissuring of the banks on both sides of the stream, the abutments having been carried forward. One of the piers has been tilted over probably by the thrust of the girder. There are no cracks in the abutments. (P. 266.)

Assam Bengal Railway (Reported by T. D. Latouche):

I went out along this line as far as the bridge over the Kapili River about forty-one miles from Gauhati. The rock cuttings, in gneiss, have not been affected in the slightest degree by the shock, but where the line passes over alluvium, the embankment has settled down, carrying the rails with it. Many of the culverts are badly cracked, apparently from the same cause as has affected the bridge mentioned above at Gauhati, viz., the fissuring of the banks of the streams and the consequent sliding forward of the abutments and wing walls. The piers of the large bridge over the Kapili are cracked through horizontally at about 2 feet above the ground level, and the girders have shifted lengthwise on top of the piers. (P. 267.)

Bridge over the Bara Khal (Reported by G. E. Grimes):

In the case of the bridge over the Bara Khal the piers have fallen right over into the river and disappeared entirely; before the earthquake this bridge had

[1] D. Kikuchi, *Recent Seismological Investigations in Japan*, Pub. E. I. C., No. 19 (Tokyo), 1904, Fig. 46.

[2] R. D. Oldham, *Mem. Geol. Surv. India*, Vol. XXIX, (1899).

eleven piers standing, each with 9000 cubic feet of masonry, there being three spans of sixty feet and six spans of forty feet, but after the shock only two piers on each bank were left standing and the intermediate space is quite blank. At the time of the shock the two embankments are said by those who were present to have moved toward one another and then apart, when the telegraph wires were snapped across and some of the insulators were hurled violently for a considerable distance backward from the river. (P. 295.)

The damage to the bridges on the Assam Bengal Railway is thus summarized by Mr. Grimes:

The abutment walls are cracked or broken and have come to, shortening the span. . . . This coming-to of the abutment walls is often quite considerable, and in spans of twenty feet it is sometimes as much as a foot. Accompanying this movement we, in almost every case, see that on one or both sides of the bridge the embankment has sunk several feet. When the bridges have wing walls to the abutment, this forward movement has cracked and considerably damaged them, but where, as in the case of many of the smaller bridges, there are straight return walls, the pressure has acted along the length of the walls and not across them, and so the bridges have mostly escaped with little or no damage. The coming to of the abutments and consequent shortening of the span has either resulted in the buckling up of the girders in the center, or the girders have pushed back on and broken off the balance walls of the abutments. In a few cases the piers of the bridges have been tilted over to the side, but in most cases only inwards. (P. 296.)

Gauhati Road Bridge over Umkra River:

The large bridge on the Gauhati Road about one and one-half miles from Shillong, over the Umkra River, has suffered severely. The abutment on the southeast side fell entirely, carrying the girders with it. The two piers and the abutment on the northwest side, which are of more recent construction, remained standing, though somewhat cracked. (P. 271.)

Bridge near Shampur on Kuch Bihar Railway:

Near Shampur, also, the hexagonal brick piers of one of the bridges have been broken through horizontally and the upper portion has shifted slightly: this form of fracture appears to have been rather common, and though at first supposed to be of no great moment, was subsequently found to render the bridges unsafe for either rapid or heavy traffic. (P. 284.)

Bamboo bridges over canal (reported by H. H. Hayden):

The canal being, as already stated, a line of weakness, it is not surprising to find that the banks on each side are cut up by fissures, while its bed has risen in some cases through several feet, the central portion being now above the water: this is well shown by the bamboo bridges which have been shot up in the center (see Fig. 4, *A*). The same effect is seen in numerous places between Rangpur and Kuch Bihar, where bridges of small span cross canals or swamps. If the

bridge has a central pier then the pier has been shot up and the bridge broken. This is, however, in some cases due partly to a sinking of the abutments as well. (P. 285.)

Manshai Bridge:

In the neighborhood of Dewan Hat, however, the line has suffered severely, and the bridges, particularly that over the Manshai River, have been broken

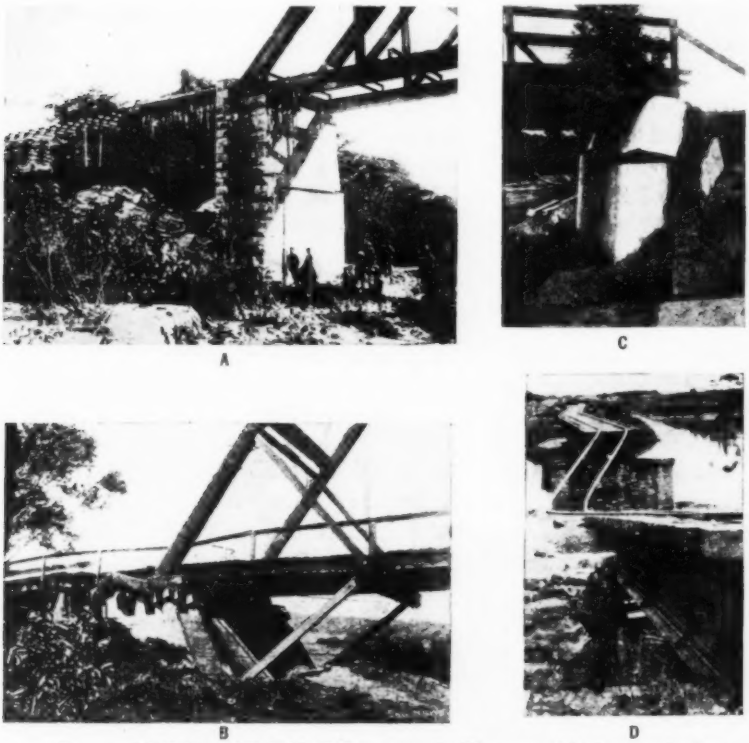


FIG. 5.—(*A*) Bridge of Tokaido Railway near the Kisogawa with abutment broken by the approach of river banks during Japan earthquake of 1891 (after Milne and Burton). (*B*) Bridge over Salinas River with distorted abutment damaged during California earthquake of 1906 (after Derleth). (*C*) County bridge over Pajaro River at Chittenden, California, after the California earthquake of 1906 (after Dudley). (*D*) Manshai bridge after the Assam earthquake of 1897 (after Oldham).

(see Fig. 5, *D*). At about seven miles south of Kuch Bihar, a small bridge passing over a water channel in swampy land has been damaged by the thrusting-up of the central pier. (P. 287.)

Examination of the photograph of the Manshai bridge reproduced in Fig. 5, *D*, will show in the lateral kink of the rails and the dropping of the span conformity with the general rule that there is a shortening of the distance between piers.

CALIFORNIA EARTHQUAKE OF APRIL 18, 1906

The report upon this earthquake[1] purporting to discuss the effect on structures particularly is a disappointment in that a single bridge only is mentioned, and this in such ambiguous language that the nature of the damage sustained can only be guessed.[2] The bridge referred to is that of the Southern Pacific Railway where it crosses the Pajaro River near Chittenden Station. Abundant material for a study of the damage to bridges existed, and we are fortunate in having been able to collect the data concerning some interesting examples. One of these is illustrated by a photograph of the county bridge over the Pajaro River at Chittenden, which, as well as any we have seen, illustrates a typical effect of earthquakes upon such structures (see Fig. 5, *C*).[3]

The damage sustained by the Salinas Highway Bridge in the same province has been described and photographed by Derleth[4] (see Fig. 5, *B*), and is shown to conform to the rule which elsewhere obtains. The bridge rests on pile-bent abutments. The north abutment was not disturbed, but the south abutment was bent back from the river at the top and it is stated that the ground moved out toward the river beneath it a distance of six feet. A three-inch oil pipe-line crossing the bridge was bent into an *S* and ruptured.

In the same article Derleth has given us a clear account of the damage to the Southern Pacific Railway bridge over the Pajaro River, from which it appears that this case is an unique exception to

[1] Grove Carl Gilbert, Richard Lewis Humphrey, John Stephen Sewell, and Frank Soulé, *The San Francisco Earthquake and Fire of April 18, 1906, and Their Effect on Structures and Structural Material*, Bull. 324, U. S. Geol. Surv., 1907, pp. 170, pls. 56.

[2] *Loc. cit.*, p. 20, Pl. XI *A*.

[3] Reproduced in Salisbury's *Physiography* (New York, Holt & Co., 1907), p. 424.

[4] Charles Derleth, Jr., C. E., "The Destructive Effect of the San Francisco Earthquake of 1906," *Engineering News*, Vol. LV, No. 26 (June 28, 1906), p. 712, Figs. 15 and 16.

the general rule. The bridge lies across the rift line of California at a very acute angle and it is probable that the large shiftings on this line have here played an important rôle in producing the damage.[1] The pulling of the girder out of its seat on the south abutment apparently indicates a widening of the distance between banks during the earthquake, and this would appear to show that the shear on the rift plane is here in a contrary sense to that which has generally obtained at other places.

Through inquiry of the engineering department of the Southern Pacific Railway Company it was found that in addition to the Pajaro bridge above mentioned slight damage was sustained in other sections of the road. Some few trestles were thrown out of line and "two small drawbridges were affected slightly by the movement of the landing piers toward the center piers—just enough in each case to bind the bridge."[2] On the Atchison, Topeka and Santa Fe Railway there was a Bascule bridge in which the two leaves approached each other so closely, as a result of the disturbance, that the bridge was rendered inoperative until changes were made. This gradual approach of the two abutments has continued in the absence of sensible shocks during the succeeding two years.[3]

In the report of the subcommittee on railway structures to the General Committee of the American Society of Civil Engineers[4] it is stated that embankments crossing marshy ground generally sank (sometimes as much as eleven feet), and that trestles in soft material moved or were thrown down. Railway drawbridges across little creeks and inlets about the Bay of San Francisco "were affected by a slight movement of their piers, in many cases resulting in the bridge binding so that it could not be opened until some repairs were made." On the California and Northwestern Railway the bridge at Bohemia and the one over the Russian River at Healdsburg were

[1] *Loc. cit.*, p. 711.

[2] Letter from J. H. Wallace, Assistant Chief Engineer, Southern Pacific Company.

[3] Letter from H. C. Phillips, Chief Engineer, A. T. and S. F. Ry. Co.

[4] "The Effects of the San Francisco Earthquake of April 18, 1906, on Engineering Constructions," Report of a general committee and six special committees of the San Francisco Association of Members of the American Society of Civil Engineers (with discussions by twenty-three others, Ed.), *Trans. Am. Soc. Civ. Eng.*, Vol. LIX, (December, 1907), pp. 208–329.

both slightly shifted on their piers at one end. At Duncan's Mills on the North Shore Railroad a combination span a hundred and twenty feet long "had the eye-bars in the lower chord buckled by movement of the abutments toward each other" (see Fig. 6, *B*).[1]

The sub-committee appointed to investigate highway structures in lieu of a report offered the statement that such structures had been singularly immune from damage. This meager statement is curiously contradicted by the evidence furnished in the printed discussions. The highway bridge across a creek tributary to Tomales Bay near Port Reyes Station, which had eight panels or sections, had its north abutment sink two to three feet and approach the south abutment so much that in reconstruction the north end panel was not used but was in part replaced by an apron (see Fig. 6, *C*).[2] At Watsonville was a bridge which according to Derleth was distorted in the same manner as the Salinas bridge above described and with which it is compared.[3] In each case the deformation was ascribed to "differential surface movement distinct from elastic vibration."

Two additional instances have been mentioned in the report with illustrations by Galloway,[4] to wit: the Alder Creek bridge north of Point Arena in Mendocino County, the other the Gualala bridge south of the same point. The first mentioned (Fig. 6, *D*) now lies on the bed of the stream across the rift line, the other, a steel structure, had one end of the girder dropped twenty-eight feet. These bridges were not examined by the engineers, and the views afford the only evidence at hand.

KINGSTON EARTHQUAKE OF JANUARY 14, 1907

A very recent example which illustrates the usual deformation of a bridge at the time of a destructive earthquake, has been furnished

[1] J. H. Wallace, H. C. Phillips, R. M. Drake, and E. M. Boggs, sub-committee, *loc. cit.* p. 259, Pl. 53, Fig. 1.

[2] H. H. Wadsworth, *M. Am. Soc., loc. cit.*, p. 270.

[3] Charles Derleth, *loc. cit.*, pp. 311–15.

[4] John D. Galloway, *M. Am. Soc. C. E., loc. cit.*, Pls. 57, 58. From a personal letter from Mr. Galloway it is learned that Alder Creek enters the ocean some twenty miles north of Point Arena. The Gualala River is a mountain stream which enters the ocean about the same distance south of Point Arena. The Gualala bridge, which was built some ten years ago, gave trouble from the fact that the ground beneath the piers showed a tendency to slide so that it was necessary to put the bridge up upon a false work and realign the piers.

FIG 6

by Fuller's account of the Jamaican earthquake of January 14, 1907.[1] A cement culvert at the mouth of a stream was buckled up and broken through the movement of its walls toward the center of the valley (see Fig. 4, *D*).

It is believed that the above data are sufficiently full and decisive to warrant the conclusion that during a destructive earthquake the banks of valleys generally draw together so as to shorten the intervening distance. The examples of deformed bridges which have been offered in evidence, have not been selected for the purpose of proving a point, but include all which have come to the writer's attention. The unique exception to the law which otherwise controls, is furnished by the railway bridge over the Pajaro River damaged during the California earthquake of 1906; and, inasmuch as this bridge lies across the rift line at an acute angle it seems likely that special shearing movements along the rift plane have here been of larger measure than the normal contraction of the valley.

It appears, further, to be a fact of general observation, that a fissure or series of parallel fissures open during earthquakes along the banks of rivers parallel to their courses (see Fig. 3, *C*). According to Milne[2] within the Aichi prefecture in Japan, after the earthquake of 1891, more than four hundred miles of river banks, water trenches, and roads were found destroyed through action of this kind. On river banks the fissured zone and hummocky ground looked as though gigantic plows had torn out furrows several feet in width and sometimes as much as twenty feet in depth, and this character of the surface extended from ten to fifty yards from the river. Such structures can be only in part explained through the shaking down of loose material such as is found in a railway embankment on which the tracks approach bridges, for the reason that such mere removal of support to rails should give the effect of tension rather than compression.

Thomas Oldham, who first seriously studied the fissured river banks in connection with the Cachar (Indian) earthquake of January 10, 1869,[3] went out from the conception of an earthquake centrum

[1] M. L. Fuller, "Notes on the Jamaica Earthquake," *Jour. Geol.*, Vol. XV, 1907, pp. 718, 719.

[2] John Milne, *Seismology*, p. 148.

[3] *Quart. Jour. Geol. Soc. Lond.*, Vol. XXVIII (1872), p. 255. See also *Mem. Geol. Surv. India*, Vol. XIX, Pt. 1, pp. 52–56, Pl. vi.

explained the cracks as due to earth waves, and assumed that a single crack, if one only was formed, opened just a half-wave-length back from the river's edge on either side.

When we take into account the observed effect of the earth movements upon bridges, it is clear that something quite different from the mere passage of an earth wave must be invoked in order to explain these geological changes. Not only is the space between valley walls in part closed up, but for a considerable distance back from the banks the bridge approaches show the effect of compression (see especially Fig. 1, *A*). The piers of the bridge which rest upon the stream bed also suffer changes not explainable, upon Oldham's theory (see Fig. 3, *A* and *B*). Whether occupied by streams or not (see Fig. 3, *D*) it seems to be clear that the vicinity of valleys is marked by unusual surface compression in a direction at right angles to the valleys.

It is perhaps unnecessary to here bring forward the evidence obtained from observations of a different kind that local compression of the ground actually occurs during earthquakes. On the one hand, there are the continuous stone curbings and buried metal pipes which are found buckled up from the surface of the ground; and on the other, there are the many variations in the longitudinal shear along fault lines which must be accounted for either through differential contraction, expansion, or both.[1] On the Baishiko fault opened in Formosa on March 17, 1906, a change in the direction of the longitudinal shear between two stations less than three-fourths of a mile apart, indicated a change in linear distance between the two points before equally distant of about fourteen feet.[2]

That the changes of superficies to which we have called attention are wholly restricted to the mantle of unconsolidated rock material is most improbable; though, as we shall see, there is reason for supposing that it is locally much larger within the mantle than within the underlying rock. To account for an extension of surface of any portion of the consolidated outer shell of the lithosphere, it is only necessary to assume a very slight increase of each of the joint spaces present within the rock. A contraction of the surface area may,

[1] For examples see the author's *Earthquakes*, pp. 62, 66, 73–75, 228–31.

[2] Omori, *Bull. E. I. C.*, Vol. I, No. 2, Pl. xvii.

perhaps, likewise be best explained through a change, and here a reduction in width, of individual joint spaces. To this change may be added the effect of some actual compression of the unfractured

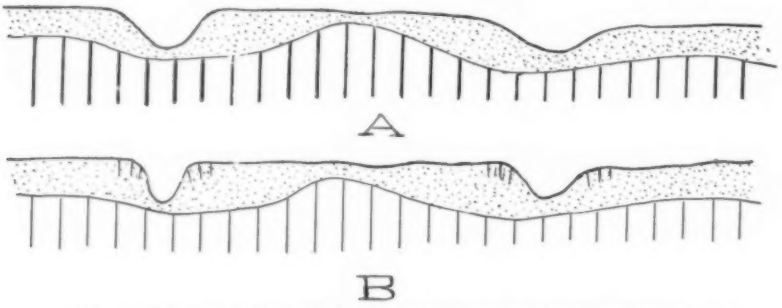


FIG. 7.—Diagram to illustrate the narrowing of valleys during earthquakes as a result of crustal contraction, (*A*) before contraction; (*B*) after contraction.

portions of the shell. In Fig. 7 let *A* represent in its lower portion a section of the outermost consolidated shell of the lithosphere, and in its upper portion the mantle of unconsolidated deposits in which the

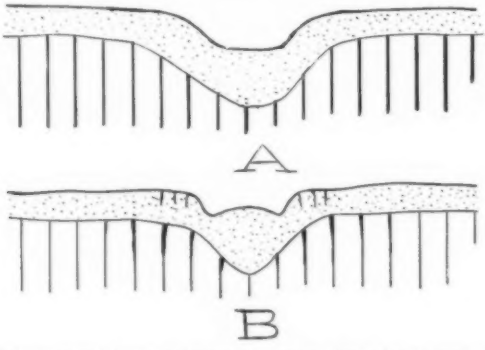


FIG. 8.—Diagram to illustrate the pushing up of the beds of rivers during earthquakes as a consequence of crustal contraction, (*A*) before contraction; (*B*) after contraction.

valleys have been cut. As the compression of the shell reduces the width of the joint spaces and otherwise diminishes the superficies of the shell, its envelop of loose material by reason of its lack of

rigidity is incompetent to transmit the same stresses, and hence tends to remain in *status quo*. In the mantle a slip over the basement floor of rock will take the place of a more uniformly distributed adjustment within the floor. The valleys which intersect the mantle, must, in consequence, reveal an amount of crustal contraction far in excess of the average for the district (see Fig. 7, *B*).

Wherever rock valleys interrupt the surface of the shell beneath a newer valley in the mantle of loose soil (see Fig. 8, *A*), that portion of the shell which lies outside the level of the bottom of the rock valley, will by reason of the breaks in its continuity be less capable of transmitting the compressive stresses. This may otherwise be expressed by saying that this outer layer is not fully included in the pinch to which the layer immediately below it is subjected. A consequent reduction of its competency to transmit the earth's stresses will be greatest for the immediate vicinity of the valleys, and hence the joints will there be closed by a portion only of the average amount. The walls of the rock valley must therefore tend to approach with the result that they will push up the center of the river bed into a definite ridge, and further give the effect of a settlement at the banks where abutments are placed (see Fig. 8, *B*). Next to the narrowing of the distance between banks and the accompanying parallel fissuring, these changes are, as we have seen, the ones most frequently observed along rivers after a destructive earthquake.

UNIVERSITY OF MICHIGAN
May 3, 1908.

THE DEVELOPMENT OF A CARBONIFEROUS BRACHIOPOD, *CHONETES GRANULIFER* OWEN

F. C. GREENE

INTRODUCTION

Through the kindness of Professor J. W. Beede the writer had placed at his disposal for study a large collection of *Chonetes granulifer*, the adults alone probably numbering two thousand specimens. The majority of these specimens are finely preserved and this together with the great range in their size, gives an excellent opportunity for a study of the development of the species.

Chonetes granulifer has been found in the following horizons arranged in descending order:

Permian Series	Ft. Riley limestone. Wreford limestone.
Pennsylvanian Series	Neosho shale. Florena shale. Cottonwood limestone. Eskridge shale. Neva limestone. Elmdale formation. Americus limestone. Emporia limestone. Burlingame shale. Howard limestone. Severy shale. Topeka limestone. Deer Creek limestone. Lecompton limestone. Oread limestone. Kickapoo limestone. Stanton limestone.

First will be taken up a study of the form from the Florena shales at Florena and Grand Summit, from which a complete series was obtained, and then a study of the development based on this series. This study has been under the direction of Professors E. R. Cumings and J. W. Beede of Indiana University, and the author wishes to

express his deep gratitude for their aid and assistance. The photographs for the plates were also made by Professor Cumings.

Owen's type specimen of *C. granulifer* came from the Carboniferous limestone, near the mouth of Keg Creek, Iowa.[1] This locality has never been definitely correlated with the Kansas section, but as near as can be made out from Meek's discussion of the rocks of the Missouri River section[2] and Owen's description[3] of the locality from which the type specimens were taken, as correlated by Beede and Prosser,[4] it appears to come from some horizon between the Topeka and the Tecumseh limestones, probably nearer the Deer Creek limestone than any other. The material which the writer used, contained specimens covering practically the entire range of the species, including the equivalent of the horizon from which the types were taken.

SPECIFIC CHARACTERS

Mature form.—Shell semi-circular in outline, having the greatest breadth at the hinge-line, with cardinal angles somewhat attenuate. The size of the shell varies greatly. Size of largest specimen, 33 mm in width by 19 mm in length. Average size of adult, 28 mm in width by 15 mm in length. The shape also varies in that the cardinal angles of some specimens are much more mucronate than in others (Plate I) and in some specimens there is a tendency to develop a mesial sinus in the ventral valve. Both of these characters are seen in Plate I, rows 3, 4.

Dorsal valve.—In the Grand Summit specimens (the most perfectly preserved in the lot) the dorsal valve is concave to the extent of two or three mm. This valve is ornamented with radiating striae and concentric lines of growth around the margin. The striae number about fifty near the beak but at the frontal margin increase to about one hundred and fifty by implantation. The shell is punctate in the furrows between the striae. The striae become obscure on approach-

[1] Owen, *Geol. Rep. Wis., Iowa, and Minn.*, p. 583.

[2] Meek, *U. S. Geol. Surv. Nebr.*

[3] Owen, *Geol. Rep. Wis., Iowa, and Minn.*

[4] Prosser, "Comparison of the Carb. and Penn. Form. of Neb. and Kans.," *Jour. Geol.*, Vol. V, pp. 1–16, 148–72.

ing the hinge-line. Immediately under the beak, this valve is at first convex, but becomes concave farther forward.

Ventral valve.—The convexity of this valve exceeds the concavity of the dorsal valve to a very great extent in some specimens. In other specimens this valve follows the dorsal valve closely. The striae of this valve are similar to those of the dorsal. Shell punctate in the furrows between the striae. What appear to be large punctae are scattered over the surface of this valve. These are lighter in color than the rest of the surface and are largest at the anterior margin, growing smaller and more thickly set toward the beak. They possibly correspond to the spines of Producti.

The beak projects slightly over the hinge-line. Cardinal area long and narrow; longer than the greatest width of the shell farther forward. It lies at an angle of 45° to the plane of the shell (Plate II, Fig. 12, 13) grooved with horizontal striae; the greater part of the area is on the ventral valve. The hinge areas of the two valves form an obtuse angle.

Two plates of the cardinal process of the opposite valve partially close the delthyrium. The hinge area of this valve is bordered by a row of seven to eleven spines on each side of the beak, growing larger toward the cardinal extremities. This valve is the larger of the two (Plate IV, Fig. 4).

Interior of dorsal valve (*Plate II, rows 3, 4*).—Convex. Hinge-line straight. The cardinal process is bifid, stands at an angle of 120° with the plane of the valve and is one millimeter in length. On the ventral side of this process is a pit which corresponds to the convexity mentioned just in front of the beak on the exterior of the dorsal valve. From the base of the cardinal process five septal ridges radiate. Two of these pass forward at an angle of 25° or 30° to the hinge-line. They also unite back of the cardinal process to form a little lip over the process. Just back and above them are the two sockets for the hinge teeth.

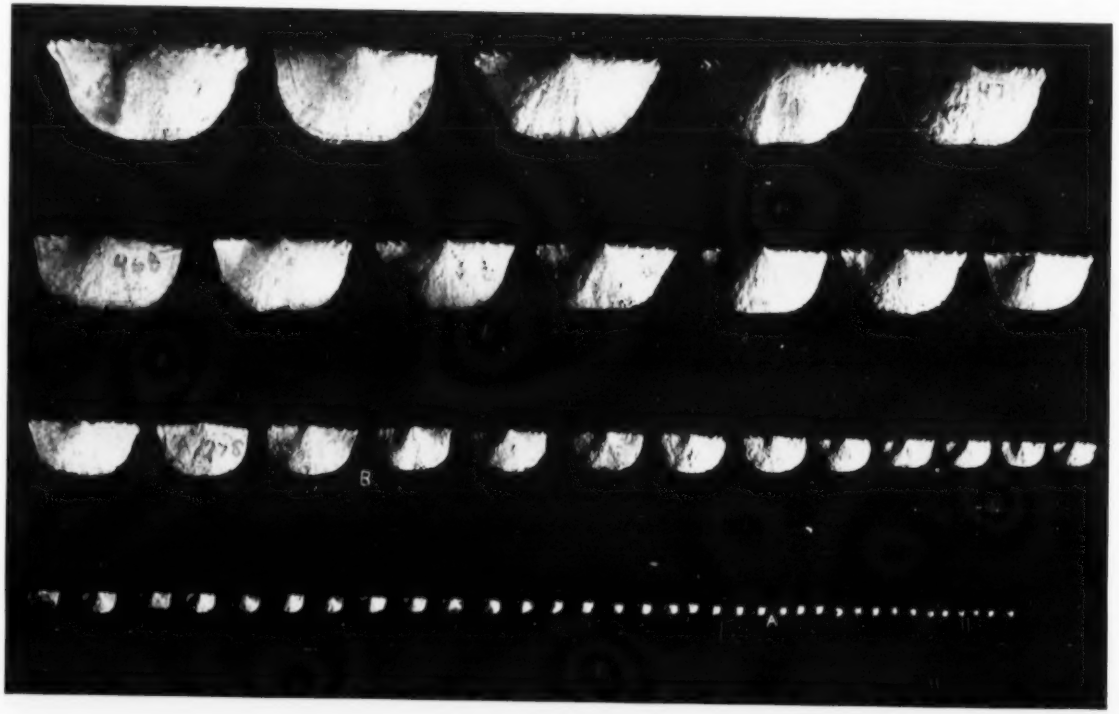
Two other lateral septa pass forward from the edge of the pit at an angle of 70° with the hinge-line. The fifth ridge is the mesial septum. It is at right angles to the hinge-line and extends forward half the length of the shell. With the other four septa it forms the boundaries of the pit. This pit was probably formed at a very young stage, and

Row IV

Row III

Row II

Row I



therefore the septa do not extend to the cardinal process as in some of the Productidae. The scars of the adductor muscles lie on each side of the mesial septum, extending over the next ridge. The brachial markings, shown on a few specimens of this valve, are somewhat obscure, and reniform in shape, pointed at the front. They lie on each side of the mesial septum, just within the row of granules marking the limits of the visceral cavity.

This valve is ornamented with granules (from which the species derives its name of *granulifer*). These are largest and most numerous at the forward edge of the visceral cavity, and the mesial sinus, growing fainter and more thinly scattered posterially. At the anterior margin they also grow fainter until they form distinct radiating rows.

Interior of ventral valve.—Very concave. Granules similar to those of dorsal valve, except that instead of having a group of granules on the anterior end of the mesial septum, they are arranged along its sides and help to form the partition between the long, median adductor muscle scars and the subovate diductor muscle scars. Hinge-line straight, with the exception of the delthyrium. There are two teeth on each side of this opening. The deltidium extends to the beak.

Nepionic form—dorsal valve.—Length 1 mm and breadth 1 mm. Longitudinally semi-elliptical in shape; concavity greater than in mature form in proportion to the size. The convexity mentioned as being opposite the beak near the hinge on the dorsal valve of the mature form, is the most prominent feature of this valve of the incipient form. Here it nearly equals the length of the shell and is more elongate than in the adult. Surface without striae.

Nepionic form—ventral valve.—This valve is also without striae. On each extremity of the hinge-line is a spine pointed laterally and posteriorly. The ventral mesial sinus is a regular feature of this valve. A sharply outlined pit also occurs regularly on this valve just anterior to the beak.

DEVELOPMENTAL CHANGES

The change in shape may be seen from the following table of the measurements of a series of specimens (not the series shown in Plate I).

1.	0.9 mm×1.0 mm	28.	5.5 mm× 3.5 mm
2.	1.0 mm×1.0 mm	29.	6.0 mm× 3.5 mm
3.	1.0 mm×1.0 mm	30.	6.5 mm× 3.5 mm
4.	1.1 mm×1.1 mm	31.	6.8 mm× 3.9 mm
5.	1.2 mm×1.2 mm	32.	7.0 mm× 4.0 mm
6.	1.3 mm×1.2 mm	33.	8.0 mm× 4.0 mm
7.	1.5 mm×1.25 mm	34.	9.5 mm× 5.5 mm
8.	1.5 mm×1.4 mm	35.	10.25 mm× 5.5 mm
9.	1.5 mm×1.2 mm	36.	11.0 mm× 6.0 mm
10.	1.9 mm×1.4 mm	37.	11.0 mm× 6.5 mm
11.	1.9 mm×1.5 mm	38.	13.0 mm× 7.0 mm
12.	2.0 mm×1.5 mm	39.	13.25 mm× 7.5 mm
13.	2.25 mm×1.5 mm	40.	16.5 mm× 8.0 mm
14.	2.25 mm×1.6 mm	41.	16.25 mm× 8.5 mm
15.	2.5 mm×1.75 mm	42.	18.5 mm× 9.5 mm
16.	2.75 mm×1.5 mm	43.	19.0 mm× 9.5 mm
17.	2.8 mm×1.75 mm	44.	21.0 mm× 9.5 mm
18.	3.0 mm×2.0 mm	45.	20.5 mm×10.5 mm
19.	3.25 mm×2.25 mm	46.	21.0 mm×10.5 mm
20.	3.5 mm×2.25 mm	47.	22.0 mm×11.5 mm
21.	4.0 mm×2.4 mm	48.	23.5 mm×12.0 mm
22.	3.9 mm×2.5 mm	49.	24.5 mm×13.0 mm
23.	3.9 mm×2.75 mm	50.	28.0 mm×13.0 mm
24.	4.0 mm×2.5 mm	51.	24.0 mm×14.0 mm
25.	4.25 mm×2.9 mm	52.	30.0 mm×15.0 mm
26.	4.6 mm×2.9 mm	53.	33.0 mm×19.0 mm
27.	4.75 mm×3.25 mm		

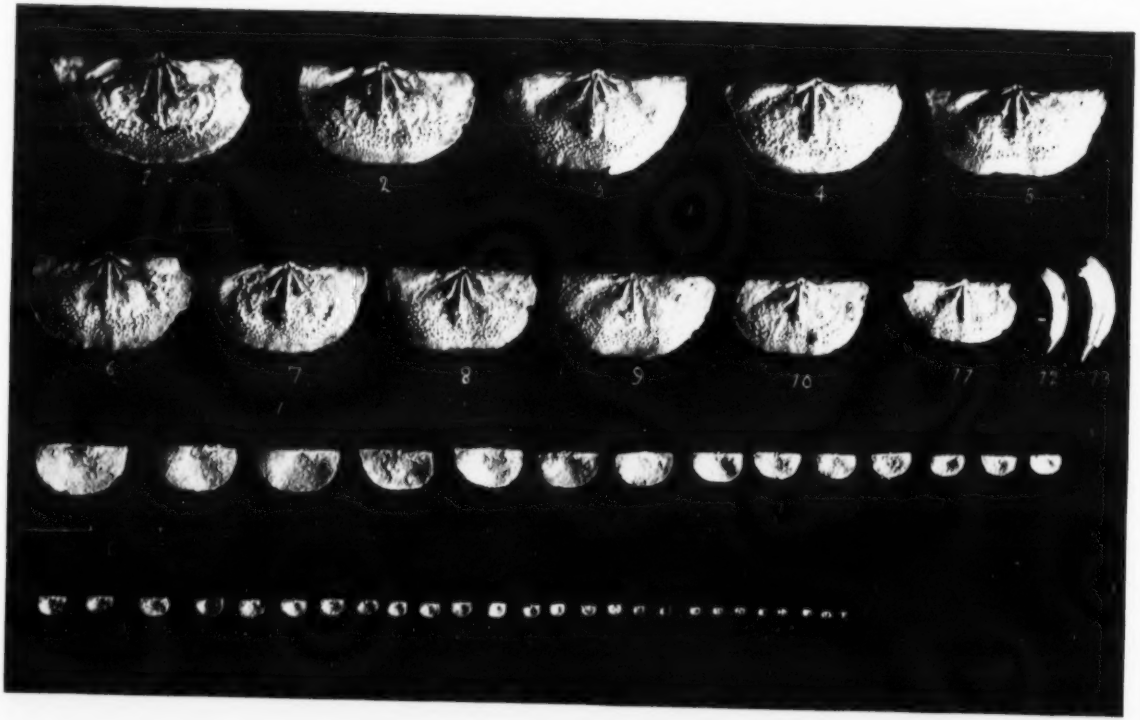
Ventral valve (Plate I).—The mesial sinus in the youngest specimen is a deep, narrow groove near the beak. This occurs regularly up to the 16th specimen, that is, one about 1.6 mm×1.2 mm in size, after which it occurs only at irregular intervals. From the youngest up, it moves forward so that in the older specimens it is seen on the anterior margin. The striae appear distinctly for the first time on the fifteenth specimen (size 1.6 mm×1.1 mm). On the youngest specimens there are two cardinal spines (Plate IV, Figs. 1–3, 6–8) one on each side of the beak. These are located on the extremity of the hinge-line in the youngest specimen, but as the hinge-line becomes longer, the spines are added successively at the extremities. No. 15 in this series shows the first traces of an additional spine, the new spine appearing, of course, between the original spine and the lateral margin. The

ROW IV

ROW III

ROW II

ROW I



number of spines increases about every eighth or ninth specimen, until it reaches the maximum of eleven on one side of the beak, or twenty-two on the entire hinge-line, which was the largest number noticed.

The shape of the youngest specimen is nearly square, while in the oldest the breadth is nearly twice the length. As will be seen by the above table of measurements, this change from one to the other is somewhat irregular.

The angle formed by the hinge-line and the sides of the shell gradually changes from an angle of 90° to a more and more acute angle, although, as has been pointed out before, the angle varies greatly in the adult (Plate I).

Dorsal valve.—The striae do not appear distinctly on this valve until the twenty-fifth specimen, (4.3 mm×2.5 mm) but this is probably due to the fact that some of the earlier stages have been omitted from this series, and that some are incrusted in the concavity or water-worn, which renders the striae invisible in them.

The most notable thing about the developmental changes in this valve concerns the small convexity mentioned in the description of the incipient form. In the smallest specimen this occupies one-half the space of this valve and extends from the hinge-line forward three-quarters of the length of the shell. In the twenty-eighth specimen it is crowded well up under the hinge-line and is so small in comparison to the size of the shell, that it is hardly distinguishable. In the oldest forms, it is so close up under the hinge-line as to be entirely obscured.

Interior of dorsal valve.—In the interior of this valve, the granules in the visceral cavity continually become fewer as the specimens become larger after the beginning of the ephibic stage. The muscular and brachial markings also become stronger as the size increases.

DEVELOPMENT

As a complete series was obtained from the Florena shales at Florena and Grand Summit, this is used as a basis of comparison. A complete series might have been obtained from Florena alone, but as the adults were compressed, Grand Summit specimens were substituted for them.

STAGES IN DEVELOPMENT

As in any series, the division into stages is more or less arbitrary, but there are several factors which determine approximately the different stages. In the series of ventral valves (Plate I, rows 1 and 2) it will be seen that all stages prior to specimen 14 (point *A* in the plate) are not marked with striae and have only the one spine (Plate IV, 1–3, 6–8) while beyond this point the striae appear and increase in number regularly (Plate IV, fig. 5). This point is taken to mark the end of the nepionic and the beginning of the neanic stage. The latter stage continues until the shell takes on its adult characters, such as the number and strength of the striae, the shape of the cardinal angles, a widening of the hinge area causing the beak to project and the hinge to appear bent. The point *B* about marks this division although it cannot be drawn with the same precision as the division between the first two stages.

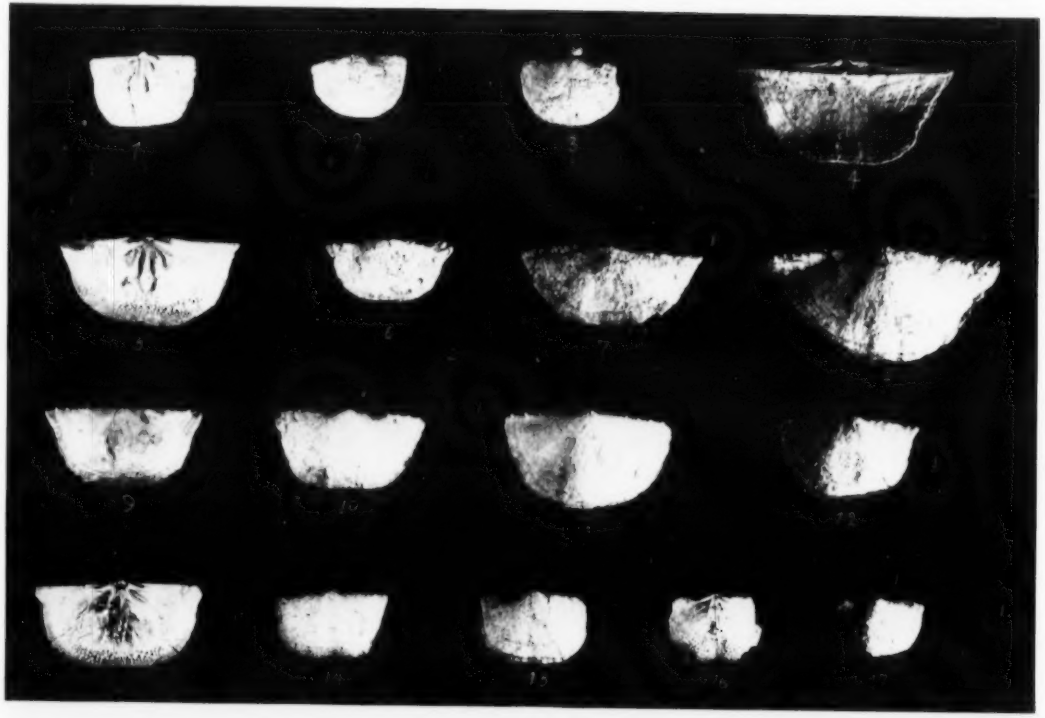
The last two (and largest) specimens in the series represent the old age or gerontic stage. The intervening specimens represent the adult or ephibic stage.

Another series is made to show further the last two stages. This is the series of specimens of the interior of the dorsal valve (Plate II, rows 3 and 4). Here the last specimen represents the gerontic stage. This shows (1) a great thickening of the shell; (2) prominence of the muscular and brachial markings; (3) greater length of hinge-line; (4) a lesser number of granules within the visceral cavity. These characters in this brachiopod are indications of old age.

COMPARISON OF THIS SERIES WITH SPECIMENS OF THE GENUS *CHONETES*, OLDER AND YOUNGER GEOLOGICALLY

It will be noted from the measurements discussed under "Developmental Changes," that the length and breadth of the shell of the nepionic stage are about equal. *This is true of practically all the Silurian and early Devonian species of Chonetes in the adult stages.*

The acceleration in the development of this species is illustrated by the appearance of a pair of spines in the nepionic stage in specimens less than 1 mm in diameter instead of in the neanic stage as in *C. scitulus*, where they first appear on specimens about 2 mm in



diameter.[1] In *C. granulifer* the youngest form obtainable has the spines on the extreme outer edge of the hinge-line.

As mentioned under the description of the Specific Characters in the incipient form of this shell, there is a deep pit or sinus just in front of the beak on the ventral side, and a corresponding convexity just in front of the hinge-line on the dorsal side. This would be an indication of an early species with these characters and also the two preceding. This form is found in the species *Chonetes lepidus* from the Marcellus shale[2] which represents the probable type of shell from which *C. granulifer* is descended.

The figure,[3] which is a ventral view, shows a deep sinus and in the description, it is stated that the dorsal side follows the curves of the ventral. It will be noted that *C. lepidus* is a striated species, while the nepionic stage of *C. granulifer* is glabrous. This has little bearing, as it is a general characteristic of the incipient shells of brachiopods to be glabrous.

Ephibic stage.—Following the laws of development, we could assume the great bulk of adults of *C. granulifer* in the upper Carboniferous of Kansas and below the Florena members of the Garrison formation to be like the ephibic stage in the Florena—Grand Summit series, and upon investigation, this proves to be the case, while above and below these limits, they should be more like the gerontic and late neanic stages respectively. This holds true in nearly every instance.

As was stated in the introduction, the type specimens probably came from a horizon between the Topeka and Tecumseh limestones. Specimens from these horizons correspond with the typical ephibic form, so that the type specimens represent just about the normal form of the species.

We find Norwood and Pratten's species, *C. smithii*,[4] that of Meek and Worthen,[5] and that of Hall and Clark[6] to be a short-eared form

[1] Raymond, *The Developmental Change in Some Common Devonian Brachiopods*, Vol. XVII, pp. 277–300. Pls. XII–XVIII.

[2] Hall, *Pal. N. Y.*, IV, Pt. 1, pp. 132 and 142, Pl. XXII, Fig. 12.

[3] *Ibid.*

[4] Norwood and Pratten, *Jour. Acad. Nat. Sci. Phil.* (2), Vol. III, p. 24, Pl. II, Figs. 2*a–c*.

[5] Meek and Worthen, *Geol. Surv. Illinois*, Vol. V, 1873, p. 570, Pl. XXV, Fig. 11.

[6] Hall and Clark, *Pal. N. Y.*, VIII, Pt. 1, 1892, XV B, Fig. 12.

with a relatively short hinge-line and the shell longer and narrower than the adult of *C. granulifer* from Grand Summit, and it is found that all these come from a much lower horizon. Thus it will be seen that they correspond to the early ephibic stage of our series. This throws them into the species *C. granulifer* as already done by Schuchert and Weller.

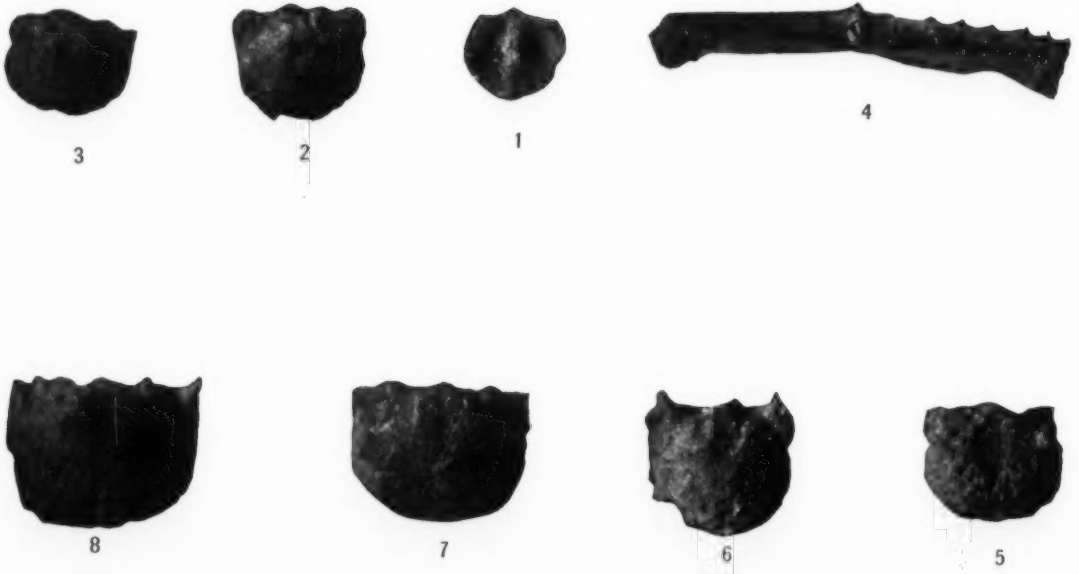
Gerontic stage.—In the case of the gerontic form we find the same thing to be true. Meek and Hayden[1] finding a form with mucronate cardinal angles, longer hinge-line, much thicker valves, and, as they say, "the area of its smaller valve ranges more nearly at right angles to the plane of the shell, than in the Illinois species"[2] (*C. smithii*), they called it a new species, although they suspected it of being allied to, or possibly the same species as, *C. smithii*. The above characters are found in the gerontic stage of the Grand Summit specimens, and Meek and Hayden's material was from a higher horizon than the Florena shales. The fact that the area of its smaller valve ranges more nearly at right angles to the plane of the shell than in the Illinois species, is due directly to the fact that it is a gerontic form. One of the characteristics of this stage is the thickening of the shell, especially in the pedicle valve, material being added to the inner surface of the shell. To compensate for this, and keep the visceral cavity its normal size, shell material is added at the hinge-line, which thickens the cardinal area of the pedicle valve and forces the pedicle valve back, making the hinge-line of this valve more nearly at right angles to that of the brachial valve (Plate II, Fig. 12–13).

In Prosser's collection from the Neosho (the next horizon above the Florena) near Strong, Kansas, the majority of the specimens exhibit a form remarkably like the gerontic stage in the Grand Summit series.

A collection from the Oread limestone at University Hill, Lawrence, Kans., made by Mr. Chas. D. Ise, bears out the foregoing conclusions to a remarkable degree. The figures (Plate III, Figs. 14–17) show a form identical in shape with the early ephibic stage in the series. The hinge-line is short and the cardinal angle is nearly or quite 90°. There is a tendency in many of the specimens to

[1] Meek and Hayden, *Pal. Up. Mo.*, p. 22, Pl. I, Fig. 5 *a–e*

[2] *Ibid.*


3
2
1
4
8
7
6
5

a comparatively deep sinus. In the interior of the dorsal valve, the granules are arranged around the margin of the visceral cavity alone. The septa are very weak when compared to the later forms.

In the Permian rocks (Ft. Riley limestone) we find that the species has reverted. This form is much smaller, has many granules on the interior, brachial and muscle markings weak, is thin shelled and approaches very nearly in shape to the nepionic stage of *C. granulifer* and therefore the earlier species of the genus. So far as is known, this is the last of the species of *Chonetes* in the Mississippi basin (Plate III, Figs. 1–3).

CONCLUSION

The writer has endeavored to show that, by taking as a basis a series of *Chonetes* from the horizon of the Upper Carboniferous, forms corresponding to the different stages may be found in the rocks above and below this. Thus the nepionic stage represents species from the Silurian and Devonian; the neanic and early ephibic species from the Carboniferous; and the later ephibic and gerontic species from the Upper Carboniferous, while the Permian or last form reverts back again in form to the early species.

EXPLANATION OF PLATES

PLATE I.—Series showing ventral view, Florena shales, at Florena and Grand Summit.

PLATE II.—Rows 1, 2, Series showing dorsal view, Florena shales, at Florena; cross-section of Grand Summit specimen; cross-section of Prosser's Neosha specimen. Rows 3, 4, Interior of dorsal valves, Florena shales at Florena.

PLATE III.—1, Ft. Riley Limestone; 2, Ft. Riley Limestone; 3, Ft. Riley Limestone; 4, Ft. Riley, No. 10, top of Neosho; 5, Neosho, Prosser's Collection; 6, Neosho, Prosser's Collection; 7, Neosho, Prosser's Collection; 8, No. 6 Crusher Hill, bottom of Neosho; 9, Florena at Grand Summit; 10, Florena at Grand Summit; 11, Florena, Ulrich's Quarries near Manhatten, Kan.; 12, Topeka, at Topeka; 13, Topeka, at Topeka; 14, Oread, University Hill, Lawrence, Kan.; 15, Oread, University Hill, Lawrence, Kan.; 16, Oread, University Hill, Lawrence Kan.; 17, Oread, University Hill, Lawrence, Kan.

PLATE IV.—1, 2, 3, 5, 6, 7, 8, specimens from the series shown in Plate I, enlarged ×20, to show details of marking ventral vein. 4, hinge area enlarged ×3. Florena shales at Florena.

THE VARIATIONS OF GLACIERS. XIII[1]

HARRY FIELDING REID
Johns Hopkins University

The following is a summary of the *Twelfth Annual Report* of the International Committee on Glaciers.[2]

REPORT ON GLACIERS FOR 1906

Swiss Alps.—Of the sixty-three glaciers observed in 1906, fifty-three were retreating and ten were doubtful. Of the doubtful glaciers nine seemed to show a slight advance but it was not sufficient to establish a true change of phase.[3]

Eastern Alps.—Only thirty glaciers were measured in 1906; they were in the Ubergossene Alm, the Silvretta, Oetztal, Stubai, Zillertal, Venediger, Glockner, Ankogel, and Ortler groups and in southern Tyrol. Twenty-six glaciers were retreating, three were stationary, and one was advancing. The general retreat was stronger than in 1905. Of the five glaciers reported as advancing and three as stationary in the Oetztal in 1905, five are now retreating. The Grosselendkees in the Ankogel, which was stationary in 1905, shows a marked advance. It is the only advancing glacier amongst those observed.[4]

Italian Alps.—All the glaciers that were observed in 1906 in Val Tournache, in Val Formazza, and in the Lombard Alps were retreating. The Forno glacier in Valfurva retreated rapidly between 1864 and 1895, and a little later became stationary. Its névé-fields seem to have diminished in the last ten years, suggesting a coming retreat.[5]

French Alps.—An examination of earlier observations has brought to light the changes which took place in the Glacier des Bossons between 1818 and 1904. At the later date the glacier was 600 meters

[1] The earlier reports appeared in the *Journal of Geology*, Vols. III–XVI.

[2] *Zeitschrift für Gletscherkunde*, 1908, Vol. II, pp. 161–98.

[3] *Report* of Professor F. A. Forel and M. E. Muret.

[4] *Report* of Professor E. Brückner.

[5] *Report* of Professor O. Marinelli.

shorter than in 1818. It seems to be advancing slightly at the present, although the other glaciers of the region, and those in the nearby regions of Maurienne and Tarantaise are retreating. Large-scale maps of the ends of several glaciers have been made for future comparisons. Several small glaciers have entirely disappeared. A number of glaciers measured in the Dauphiné are retreating rapidly and some small ones have disappeared.

Pyrenees.—The glaciers are retreating but the precipitation was heavy during the previous winter, and two glaciers are getting thicker in their upper portions.[1]

Norway.—The four glaciers measured in the Folgefon and in the Jostedal have advanced from 15 to 33 meters since 1905. In the Jotunheim seven glaciers have advanced and nine have retreated during the year. The greatest advance was 12.8 meters and the greatest retreat 22.5 meters.[2]

Russia.—Two glaciers on the northern slope of the mountain chain of Peter the Great, Boukhara, are rapidly melting back, whereas a glacier on the southern slope of the same chain is, according to observations in 1905, notably advancing. A number of glaciers are reported in the Tian Chan mountains and, although not measured, several seem to be advancing.[3]

Canada.—The report contains an interesting summary of the observations of the Messrs. Vaux on the Illecillewaet, Asulkan, Wenkchemna, Victoria, Wapta, and Horseshoe Glaciers, since 1898. It will be unnecessary to repeat the details here as the article has been published in extenso in this country.[4] Suffice to say that these glaciers have in general retreated, but at a diminishing rate; the Asulkan has advanced slightly, but has retreated again to its position of 1899; the Illecillewaet continues to retreat, but photographs show that the upper part is getting thicker, and it will be interesting to determine how soon this will affect the end.[5]

[1] *Report* of M. Ch. Rabot.

[2] *Report* of M. P. A. Oyen.

[3] *Report* of Colonel J. de Schokalsky.

[4] "Observations made in 1906 on Glaciers in Alberta and British Columbia," *Proc. Philad. Acad. Nat. Sci.*, 1906, pp. 568–79.

[5] *Report* of MM. George and William S. Vaux.

Himalayan Glaciers.—Steps have been taken by the Geological Survey of India to survey and mark the positions of the ends of several glaciers; photographs will be taken and observations made at future times, which will determine the changes they undergo.[1]

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1907[2]

The snow fall in the Rocky Mountains was so great during the previous winter that the Hallet glacier in Colorado was not uncovered during the summer of 1907, and therefore it is probable that it has made a small advance (*Mills*). Three small glaciers are reported in the Crazy Mountains of Montana, one each in Big Timber, in Sweet Grass and Rock Creek canyons, respectively (*Wolfe* and *Mansfield*). There is no report on the Californian glaciers, but the snow-fall in the Sierra Nevadas was unusually great during the preceding two winters (*Le Conte*).

The snow fall seems also to have been excessive in the Cascade Mountains of Oregon, though the annual precipitation at Portland, Oregon, was but normal (*Montgomery*). The Eliot Glacier, on the northern side of Mt. Hood, continues to retreat. A comparison of a photograph taken in 1907, with earlier ones, shows a marked recession, and the slope at the end of the glacier is much diminished, (*Langille*). Mr. A. H. Sylvester[3] has made a topographic map of Mt. Hood and the region west of it which is to be published by the United States Geological Survey. He observed glacial scratches and old moraines at a considerable distance from the mountain. He reports evidences of a small advance in most of the glaciers which is referable to the heavy precipitation during recent years, but he thinks the Zig Zag and White River glaciers are retreating on account of the greater activity of the fumarole at their heads, which has melted a large quantity of snow in the old crater of the mountain. In the canyon below White River Glacier he has found ice buried in places by more

[1] *Report* of M. Douglas W. Freshfield.

[2] A synopsis of this report will appear in the *Thirteenth Annual Report* of the International Committee. The report on the glaciers of the United States for the year 1906 was given in this *Journal*, Vol. XVI, pp. 51–55.

[3] "Is Our Noblest Volcano Awakening to New Life?" *Nat. Geog. Mag.*, July, 1908, Vol. XIX, pp. 515–25.

than 200 feet of débris, which he takes to be all morainic. This ice occurs under what has been called the Moraine Mesa, as its surface is covered by a well marked ground moraine. Mr. Sylvester looks upon the material below this moraine as an earlier moraine; between the two is a confused mass of forest humus and broken trees, some of which seems still to be in place; and he infers two periods of glaciation separated by a long interval with a mild climate. The present writer, who visited the mountain in 1901,[1] looks upon the lower material as ejecta. The presence of ice under it would then indicate that an older glacier was buried under the material thrown out during a period of great activity; and the steam which would continue to escape, in gradually diminishing quantities, would prevent the formation of glaciers for a long time; even after the snow again began to accumulate, it would require a century or more before the White River Glacier would extend to the region of the Moraine Mesa; and no great variations of the climate would be necessary to account for the buried forest. It is not improbable that the great outburst was the cause of the disappearance of the southern wall of Mt. Hood's crater.

Mr. George Davidson made a trip in southeastern Alaska in 1907 and noticed a general retreat of the glaciers and diminution of the snow-fields since his earlier visits in 1867–69. The only definite information we have regarding Glacier Bay is contained in two short notes by members of the International Boundary Survey.[2] A small sketch map of Muir and Reid Inlets accompanies Mr. Morse's report. These notes show that between 1894 and 1907, Muir Glacier has retreated eight miles, Grand Pacific Glacier, seven and one-half miles, and Johns Hopkins Glaciers, three miles. Only a small part of the end of Muir Glacier is discharging ice-bergs.[3] That the rapid retreat common to all the glaciers of the bay was in

[1] "The Glaciers of Mt. Hood and Mt. Adams," *Mazama*, 1905, Vol. II, pp. 194–200; and "Studies of the Glaciers of Mt. Hood and Mt. Adams," *Zeitschrift für Gletscherkunde*, 1906, Vol. I, pp. 113–32.

[2] Otto J. Klotz, "Recession of Alaskan Glaciers," *Geog. Jour.*, 1907, Vol. XXX, pp. 419–21; Fremont Morse, "The Recession of the Glaciers of Glacier Bay, Alaska," *Nat. Geog. Mag.*, 1908, Vol. XIX, pp. 76–78.

[3] It is to be noted that Mr. Klotz interchanges the names of the Grand Pacific and the Johns Hopkins glaciers.

some cases started, and in others helped, by the earthquake of September, 1899, has been the general belief on account of the great quantity of floating ice which the excursion steamers encountered the following summer, and which has ever since filled the bay, especially from Muir Inlet southward. This belief is confirmed by the experience of Mr. August Buschmann, who was in charge of the cannery at the mouth of the bay in 1899. He reports that immediately after the earthquake the quantity of drift ice in the bay increased and made navigation very difficult for his small steamers.

The glaciers descending from the Brabazon range of mountains, facing the coast between the Fairweather Range and Yakutat Bay, give evidence that they are retreating by the existence of moraines at some distance from the ice; the intervening region is barren, but trees in general grow on the outer side of the moraines. One glacier, the Yakutat, has its origin in the great snow fields behind the mountains and passes completely through the range; it is retreating like the others.[1]

The interpretation heretofore put upon the narratives of Malaspina and of Vancouver, regarding the ice in Disenchantment Bay, has been that the glaciers actually filled the bay as far as Haenke Island in 1792 and 1794. But Messrs. Tarr and Martin,[2] by a consideration of the general character of the vegetation, the absence of lacustrine deposits in the lower part of Russell Fiord, the strongly marked shore lines in Disenchantment Bay, and finally by a critical examination of the accounts of the two early explorers, have concluded that they merely encountered compact floating ice in the neighborhood of Haenke Island, and that the glaciers did not, at the time of their explorations, extend to this island.

In the Aleutian Islands, the volcano of Makushin, Unalaska, and the volcanic mountains of Atka, carry large névé-fields with radiating glaciers; they do not show any signs of retreat; it is probable that they are advancing, for the Aleutian Islands are unquestionably in process of elevation (*Jaggar*).

[1] Eliot Blackwelder, "Glacial Features of the Alaskan Coast between Yakutat Bay and the Alsek River," *Journal of Geology*, 1907, Vol. XV, pp. 415–33.

[2] "Position of the Hubbard Glacier Front in 1792 and 1794," *Bull. Am. Geog. Soc.*, 1907, Vol. XXXIX, pp. 129–36.

Reviews

The Stratigraphy of the Western American Trias. By J. P. Smith. Sonderabdruck aus der Festschrift zum siebzigsten Geburtstage von Adolph v. Koenen gewidm. v. seinen Schülern. Stuttgart: E. Schweizerbartsche Verlagsbuchhandlung, 1907.

Since Lower Triassic times, and perhaps earlier, the marine faunas of western America have shown a close relationship with those of eastern Asia, except when modified by the periodical invasions of Boreal forms and the occasional interruptions of Mediterranean types which gained access through Atlantic waters. At the present time the living marine faunas of Japan and our Pacific coast show a large number of identical species, though the intermingling of the shallow-water forms is prohibited by deep water east of Kamchatka and by the cold current from Bering Sea. A rise of 200 meters would close Bering strait and shut off the cold water from the north, while a greater elevation would allow easy communication between the shore forms of Kamchatka and the Aleutian Islands. It is probable that the recurrence of comparatively small elevations and subsidences of the North Pacific border accounts for the similarity of the faunas of the eastern Asiatic and the western American coasts during some stages and the invasions of Boreal types during others. This hypothesis assumes that a uniform temperature did not necessarily exist over the entire earth previous to the Tertiary, and it aims to show that the intervention of a Pacific continent during Mesozoic time is unnecessary for the explanation of the similarity of Asiatic and American faunas. An analysis of the Triassic formations of western America and a summary of later stratigraphy forms the basis for these conclusions. H. H.

The Green Schists and Associated Granites and Porphyries of Rhode Island. By Benjamin K. Emerson and Joseph H. Perry. U. S. Geological Survey, Bulletin No. 311; 71 pp., map. Washington, 1907.

This paper deals principally with the interesting Cambrian remnants which occur in Rhode Island as broad isolated patches, and with the surrounding eruptives. Special emphasis is placed on the remarkable series

of fresh porphyritic rocks which extend westward from the town of East Greenwich, although the Cambrian and Carboniferous sedimentaries and the various Paleozoic igneous rocks of this difficult area are not neglected. A complex collection of igneous rocks was intruded into the Cambrian schists, in Carboniferous times or earlier, as a laccolithic mass. A narrow basic border on the northern side of this mass passes on the south into a broad band of the granitic nucleus, while still farther south are extensive microgranites and graphic microgranites. The microgranites and the basic rocks of the narrow border seem to be portions of a common mantle over the granite. Fragments of the graphic microgranite in a blue quartz-porphyry cement constitute a breccia in the central area. After the consolidation of the granite and the rocks of its mantle, microgranite dikes penetrated the mass; then an explosive eruption blew off this microgranitic capping and furnished the numerous fragments of that rock found in the adjacent Carboniferous conglomerate. A portion of the magma left in the conduit solidified to form the central mass of porphyry; while another part, already partially crystallized, cemented shattered fragments of the graphic microgranite when a sudden transference to a higher level caused a rapid consolidation. In the comparatively quiet period following this eruption, the Carboniferous conglomerates containing bowlders of these igneous rocks were spread still more widely over the region. The conglomerates afterward suffered considerable metamorphism, so that their paste was converted into a coarse muscovite schist and many secondary minerals were developed. The publication of this bulletin will go a long way toward clearing up the very complex geological history of Rhode Island.

H. H.

Some Principles of Seismic Geology. The Geotectonic and Geodynamic Aspects of Calabria and Northeastern Sicily. By WILLIAM HERBERT HOBBS. Sonderabdruck aus Gerlands Beiträgen zur Geophysik. Bd. VIII, Heft 2, s. 219–362. Leipzig: Wilhelm Engelmann, 1907.

The author of these two articles, in an endeavor to gain more light on the crustal architecture of regions like the New England states, was on his way to Calabria when the disastrous earthquake of 1905 occurred in that province. His observations were thereby greatly facilitated. The first monograph deals in a broad way with seismic phenomena and their relation to certain geological problems. Data gathered from the communes damaged by earthquakes leads to the conclusion that they are usually arranged along

essentially straight lines which bear some relationship to geologic boundaries, coast lines, mountain borders, etc., which are parallel to one another in series, and which often intersect volcanic vents. Seismic intensity does not vary with distance from any point or points within the earth, but is greatest at or near the intersections of these seismotectonic lines. In only a very few cases can seisms be said to owe their origin to vulcanism; the great majority of shocks are due to faulting of the normal type and it is along fractures that the earth-waves are propagated. Places situated even a short distance from fracture lines along which disturbances have repeatedly occurred have escaped serious injury. It is interesting to note also that brontidi, the deep rumblings heard commonly in certain localities, occur on lines along which much seismic disturbance has taken place, indicating that these noises are due to slipping along fracture planes. A survey of recorded earthquake scarps and fissures seems to show that notable surface dislocations are formed only at times of notable shocks; that they are sharply divided into two orders of magnitude; that the faults are of the nearly vertical normal type, and that all the movements are due to an adjustment in position of individual blocks. Thus a careful study of the earth movements of a region may furnish data from which the position of otherwise undeterminable fault planes and systems may be derived. The topography and hydrography of many areas is also modified along seismotectonic lines, as is illustrated in the United States by the Northern and Southern Fall lines, the Carolina coast line, the Connecticut line, and other lineaments. The three most prominent seismic areas of the United States—the Atlantic border, the middle Mississippi basin, and the bay of San Francisco—are also sinking areas. Briefly stated, the law of the distribution of seismic phenomena is that seismicity is localized along faults and is greatest at their intersections.

The second article deals more in detail with the southernmost portion of the Italian peninsula and with the neighboring parts of Sicily. In this region the relationship between the topography and crustal dislocations is particularly well marked and the rectilinear stretches of coast are often lines of great seismicity. Even the separation of Sicily from Calabria and from Africa is a comparatively recent event due to subsidence along fault planes. The well-known Italian volcanic vents are often situated at the intersections of fracture planes, while the destructive intensity of Calabrian quakes is greatly augmented at similar points. A striking fact in connection with the best-known earthquakes of Calabria is the nearly constant relative intensity shown at a number of the affected communes, indicating that these shocks have been the results of successive

slippings along the same fault planes or that the elastic waves have been transmitted mainly along these planes. Adjustments of smaller amplitude have occurred along other planes but in no case is there any evident relation to an epicenter. H. H.

Drumlins of Central Western New York. By H. L. FAIRCHILD. New York State Museum, Bulletin 111; 76 pp., 20 pl., map. Albany, 1907.

New York possesses the most remarkable group of drumlins in the world, and this bulletin, with its excellently prepared maps, photographs, and descriptive matter, will be a welcome addition to a glaciologist's library. The distribution of the New York drumlins shows that they were formed during the latest phase of glaciation by the spreading of the ice from the Ontario basin. A sliding movement of the lower ice caused by a horizontal thrust from behind seems to be essential to drumlin formation, though the quality, position, and volume of the drift material, and the degree of the vertical pressure and of the mobility of the ice are also factors. The shales of central New York furnished a peculiarly adhesive drift from which the drumlins were *constructed* by a plastering-on process. These masses of drift were thus given their peculiar shapes by the rubbing action of the ice movement during the final stages of diminished pressure and lagging flow. The presence of open spaces in the midst of strongly drumlinized areas is difficult of explanation. In some cases depressions may have lain at such a low level that a plane of shearing was formed in the ice above them so as to leave a mass of stagnant ice beneath. An earlier ice invasion may have localized the drift of the ground moraine that was to be shaped into drumlins by the next invasion; but no drumlin was observed, the internal structure of which revealed a direct derivation from terminal moraine material.

H. H.

Geology and Water Resources of the Bighorn Basin, Wyoming. By CASSIUS A. FISHER. U. S. Geological Survey, Professional Paper, No. 53; 51 pp., 20 pl., map. Washington, 1906.

The region described comprises about 8,500 square miles, situated mainly in Bighorn County in northwestern Wyoming. The most striking topographic feature is a broad structural valley bounded on nearly all sides by high mountain ranges and containing in its interior high badland slopes. The amount of water in the principal streams varies greatly with the season of the year, being greatest in early summer; but irrigation has been prac-

ticed for over twenty years. A storage reservoir and canals under construction by the Government will reclaim 282,000 acres more. The study of the stratigraphy of the region shows that all the younger systems are represented down as far as the Devonian, and below that the Ordovician, Cambrian, and pre-Cambrian occur. The Laramie has a much greater development than any other co-ordinate division, although the Colorado, the Pierre shale, and the Wasatch also show considerable thicknesses. Coal has a widespread distribution in the Laramie and associated formations and is mined at numerous points along the streams. Gypsum deposits are extensively developed, but are not utilized except in a small way.

H. H.

Geology of the Long Lake Quadrangle. By H. P. CUSHING. New York State Museum, Bulletin 115; 88 pp., 20 pl., map. Albany, 1907.

The Long Lake quadrangle is situated on the western border of the more rugged portion of the Adirondack Mountains. The topography of the area is greatly diversified, for portions of both the high Adirondack region and the lower "lake belt" are included. Fifty-seven lakes and ponds, many being rapidly converted into marshes, are shown. All the rocks of the quadrangle are of pre-Cambrian age and most of them belong to the early portion of that long interval. Four groups have been differentiated, most of them strongly metamorphosed: (1) A series of sedimentary rocks, the Grenville series, with contemporaneous intrusions; (2) a series of gneisses of igneous origin, perhaps older than the Grenville; (3) a series of igneous rocks less profoundly altered and certainly younger than the preceding; (4) a series of still younger igneous rocks of very slightly altered character. Probably Ordovician deposits were laid down on the older rocks but, if so, have been entirely removed by erosion. A full account of the geological history of the northern Adirondack region is given by the same author in New York State Museum Bulletin No. 95.

H. H.

Mineral Solution and Fusion under High Temperatures and Pressures. By ARTHUR L. DAY. From the *Fifth Year-book* of the Carnegie Institution of Washington, pp. 177–85. Washington, 1907.

This paper is a summary of the work accomplished in geophysical research by the Carnegie Institution of Washington in 1906. The work

has now passed beyond the preliminary stage. Important results have already been obtained and much more may be expected in the future, especially since the occupation of new quarters by the laboratory will make possible the investigations of mineral behavior under high pressures originally contemplated. The study of the feldspars and other minerals resulted in the location of several cases of reversible changes and one of irreversible change. Wollastonite possesses one crystal form below 1,200° and another above that temperature and either of these forms may be changed to the other. Three forms of magnesium metasilicate may be changed into a fourth by heating, but the reverse change does not occur; and yet enstatite, the magnesium silicate compound common in rocks, is not this stable form. Quartz was found to change over to tridymite at 800°, if given time enough; showing that this mineral, so common in nature, has been formed at a relatively low temperature. "Quartz-glass," a most useful material which can be raised to a white heat without melting and subjected to sudden changes of temperature without breaking, was successfully prepared, though quite high temperatures (above 1,600° C.) and some pressure were necessary. The valuable properties of Portland cement have been attributed to tricalcic silicate, but this compound was found not to exist; further study may reveal the true chemical relations which determine the action of this cement. Textures similar to those of certain schistose metamorphic rocks were produced in the laboratory by submitting crystallizing substances to unequal stresses; thus confirming the conclusions of Van Hise in regard to the cause of schistosity in rocks. The published work of the laboratory has appeared in various scientific journals, as enumerated in the paper.

H. H.

The Mountains of Southernmost Africa. By W. M. DAVIS. Reprinted from Bulletin of the American Geographical Society, Vol. XXXVIII, October, 1906.

One of the best-defined physiographic features of South Africa is the mountain system, occupying the southern border and here referred to as the Cape Colony ranges. It comprises a number of nearly parallel east and west ridges and longitudinal valleys which do not conform in direction to the trend of the southern sea coast but are cut irregularly by it. The sea has advanced on these mountains, leaving but a remnant of the whole system, and this remnant has itself suffered extensive denudation. Americans will be particularly interested to learn that the Cape Colony ranges are in many respects similar to the Alleghenies. The strata, with the exception

of a few Mesozoic formations in South Africa, are Paleozoic in both cases, and were originally spread out in horizontally uniform sheets of great vertical diversity. Great thicknesses of rock were laid down on slowly subsiding peneplains until compressional forces crowded them into parallel folds with overturns directed toward the continental center and with essentially flat plateaus on the landward side of the systems. In both cases, therefore, the mountain-making forces produced thrusts directed from the ocean toward the land masses. The massive Karroo formations in southernmost Africa, as the Carboniferous strata in the Appalachians, have been almost entirely removed from the folded area by a long period of erosion, which produced a partial peneplanation; while the renewal of deep erosion since that period is the result of another relative uplift. The present configuration of the mountains is in no sense due to the form the country received originally as a result of the action of the compressional forces, though the prevalence of anticlinal ridges and synclinal valleys has proved a snare to some observers. The synclinal valleys are occupied by *resequent*, not *consequent*, streams; the early consequent streams were diverted to the anticlines at one period, but were forced back into synclinal positions by the resistance of a second deep-lying hard stratum. Where the beds of a regularly folded region are of great vertical diversity and the geologic history is similar to that of the Alleghenies or the Cape Colony ranges, the resequent type of valley is the one which theoretical considerations indicate as the natural result of the conditions prevailing. H. H.

Drainage Modifications in the Tallulah District. By DOUGLAS WILSON JOHNSON. Proceedings of the Boston Society of Natural History, Vol. XXXIII, No. 5; pp. 211–48. Boston, February, 1907.

The Chattooga River flows southwest between Georgia and South Carolina to the westernmost point in the latter state, where it receives the Tallulah River as a tributary from the northwest and then turns abruptly to the southeast and flows to the Atlantic Ocean under the names of the Tugaloo and Savannah rivers. A few miles from this abrupt bend, Deep Creek, one of the headwaters of the Chattahoochie system, continues the course started by the Chattooga to the southwest.

The conclusion is reached that, by a process of "remote capture," the Chattooga River, which formerly flowed southwest into the Gulf of Mexico as a part of the Chattahoochie system, was captured by a member of the Savannah system. The Atlantic drainage gained this victory over that of

the Gulf by virtue of its shorter course to the sea, aided perhaps by favorable crustal warping. The place of the capture was just below the junction of the Tallulah and Chattooga Rivers. The falls and gorge of the Tallulah, difficulties in the paths of many former observers, are explained as the result of the presence of a rock barrier in that river more resistant than the formations the Chattooga was forced to cut through. Other physiographers, notably Hayes and Campbell, had reached essentially the same conclusions in regard to this capture, but it remained for this masterly exposition of the case to set at rest all doubts on the subject. H. H.

Postglacial Faults of Eastern New York. By J. B. WOODWORTH. From New York State Museum, Bulletin 107, Geological Papers. Albany, 1907.

At a number of points in and near the Hudson River Valley, as well as in various points in New England, the relation to one another of glacial striae on each side of certain fault planes shows that the displacements have taken place since glacial times. The so-called tilting of the land after the retreat of the ice has, therefore, been accompanied in this region by the fracturing of rocks in certain zones where the strata have yielded by numerous small step-faults. These have a downthrow to the southwest where the strike of the structures is normal to that direction, and to the south where the strike is east and west. The observations so far made indicate that the ancient shore lines on the eastern side of the Hudson gorge north of the Highlands have been raised a few feet more than those of the western side. Confirmation is also given to the supposition that there has been a relative uplift in the north and a downthrow in the south of this area, though it is uncertain whether the degree of faulting is a measure of the extent of the change of level. Further examination of these displacements may furnish data for the exact determination of the amount and nature of the postglacial warping to which the northeastern states have been subjected.

H. H.

Recent Publications

—Anderson, J. G. Contributions to the Geology of the Falkland Islands. [Dulau and Co: London, W. Wissenschaftliche Ergebnisse der Schwedischen Südpolar-Expedition, 1901–1903, Band III, Lief. 2.]

—Arnold, Ralph. New and Characteristic Species of Fossil Mollusks from the Oil-Bearing Tertiary Formations of Santa Barbara County, California. [From Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. L, Part 4. 28 pp., 9 pls. Washington, December 13, 1907.]

—Atwood, W. W. and Goldthwait, J. W. Physical Geography of the Evanston-Waukegan Region. [Illinois Geological Survey, Bulletin 7. Urbana, 1908.]

—Barrell, John. Origin and Significance of the Mauch Chunk Shale. [Bulletin of the Geological Society of America, Vol. XVIII, pp. 449–76. New York, December, 1907.]

—Bascon, F., and Goldschmidt, V. Anhydritzwilling von Aussee. [Sonderabdruch aus Zeitschrift für Krystallographie usw. Band XLIV, Heft 1, s. 65–68. Leipzig, 1907.]

—Beadnell, H. J. L. Flowing Wells and Sub-Surface Water in Kharga Oasis. [From the Geological Magazine, N. S., Decade V, Vol. V, February–March 1908.]

—British Association for the Advancement of Science, Report of the 77th Meeting of the. [London, 1908.]

—Brückner, Ed. and Muret, E. Les variations périodiques des glaciers. [Extrait des Annales de Glaciologie, t. II, Mars 1908, p. 161–98.]

—Bureau of Science, Sixth Annual Report of the Director of the. [Manila, 1908.]

—Cameron, F. K. and Gallagher, F. E. Moisture Content and Physical Condition of Soils. [U. S. Department of Agriculture, Bureau of Soils, Bulletin No. 50. 70 pp., 33 figs. Washington, 1908.]

—Carnegie Institution of Washington, Report of the President of the, for the Year Ending October 31, 1907.

—Clapp, Frederick G. Complexity of the Glacial Period in Northeastern New England. [Bulletin of the Geological Society of America, Vol. XVIII, pp. 505–56, pls. 57–60. New York, February, 1908.]

—Clarke, Frank Wigglesworth. The Data of Geochemistry. [U. S. Geological Survey, Bulletin 330. 668 pp. Washington, 1908.]

—Clarke, John M. Early Devonic History of New York and Eastern North America. [New York State Museum, Memoir 9. 252 pp., 48 pls., numerous figures. Albany, 1908.]

—Congrès Géologique International. Compte rendu de la X^{ème} session, Mexico, 1906. Premier et deuxième fascicules, 1,358 pp. [Imprenta y Fototipia de la Secretaria de Fomento, Callejón de Betlemitas núm. 8, Mexico, 1907.

—CORSTORPHINE, GEO. S. Reply to the Discussion on the Paper "The Occurrence in Kimberlite of Garnet-Pyroxene Nodules." [From Proceedings of the Geological Society of S. Africa, Vol. X, pp. lxi–lxiv, 1907.]

—CUSHING, H. P. Asymmetric Differentiation in a Bathylith of Adirondack Syenite. [Bulletin of the Geological Society of America, Vol. XVIII, pp. 477–92. New York, December, 1907.]

—DAVID, T. W. E. The Geology of the Hunter River Coal Measures. Part I. —General Geology, and the Development of the Greta Green Coal Measures. [Memoirs of the Geological Survey of New South Wales. 354 pp., 43 pls., 70 figs., maps and sections. Sidney, 1907.]

—DAVIS, CHARLES A. Some Interesting Glacial Phenomena in the Marquette Region. [From the Ninth Annual Report of the Michigan Academy of Science.]

———. Peat. Essays on Its Origin, Uses, and Distribution in Michigan. [Geological Survey of Michigan. Lansing, 1907.]

—DUNN, E. J. The Buffalo Mountains. [Memoirs of the Geological Survey of Victoria, No. 6. 11 pp., 53 pls., diagram, and map. Melbourne, 1908.]

—DUNSTAN, B. The Great Fitzroy Copper and Gold Mine, Mount Chalmers (Rockampton District). [Queensland Geological Survey, Publication No. 216. 36 pp., 15 pl. Brisbane, 1907.]

—ETHERIDGE, CHAPMAN, AND HOUCHIN. Paleontological Contributions to the Geology of Western Australia. [Western Australia Geological Survey, Bulletin No. 27. 43 pp., 10 pls. Perth, 1907.]

—FAIRCHILD, HERMAN L. Origin of Meteor Crater (Coon Butte), Arizona. [Bulletin of the Geological Society of America, Vol. XVIII, pp. 493–504. New York, December, 1907.]

—FARIS, R. L. Results of Magnetic Observations Made by the Coast and Geodetic Survey between July 1, 1906, and June 30, 1907. [Coast and Geodetic Survey, Appendix No. 5, Report for 1907, pp. 159–230. Washington, 1908.]

—FARRINGTON, O. C. Meteorite Studies II. [Field Columbian Museum, Geological Series, Vol. III, No. 6, pp. 111–29, pls. xxix–xliii. Chicago, October 1, 1907.]

—FERGUSON, H. G. AND TURGEON, F. N. An Occurrence of Harney Granite in the Northern Black Hills. [Bulletin of the Museum of Comparative Geology, Vol. XLIX, pp. 275–81. Cambridge, Mass., February, 1908.]

—FORBES, S. A. History of the Former State Natural History Societies of Illinois. [From Science, N. S., Vol. XXVI, No. 678, pp. 892–98, December 27, 1907.]

—FOWKE, GERARD. Surface Deposits along the Mississippi between the Missouri and the Ohio Rivers. [From the Missouri Historical Collections, Vol. III, No. 1, pp. 31–52.]

—Fraser, Colin, and Adams, James H. The Geology of the Coromandel Subdivision, Hauraki, Auckland. [New Zealand Geological Survey, Bulletin No. 4 (New Series). 148 pp., 32 pls., 11 maps. Wellington, 1907.]

—Gautier, Armand. The Genesis of Thermal Waters, and Their Connection with Volcanism. [From Economic Geology, Vol. I, No. 7, July–August, 1906.]

—Gentil, Louis. Itinéraires dans le Haut Atlas marocain. [La Géographie, Bulletin de la Société de Géographie.]

—Geological Society of Washington. Abstracts of Papers Presented during the Year 1907. [From Science, Vols. XXV–XXVII.]

—Geophysical Laboratory of the Carnegie Institution of Washington. Annual Report of the Director, 1907. [From the Yearbook No. 6, pp. 85–96, pls. 6–7.]

—Gibson, Chas. G. The Geology and Mineral Resources of Lawlers, Sir Samuel, and Darlot (East Murchison Goldfield), Mt. Ida (North Coolgardie Goldfield), and a Portion of the Mt. Margaret Goldfield. [Western Australia Geological Survey, Bulletin No. 28., 67 pp., 3 maps, 5 plans. Perth, 1907.]

—Gilbert, G. K. Lake Ramparts. [From the Sierra Club Bulletin, No. 37, pp. 225–34. January, 1908.]

—Gordon, W. C. and Lane, A. C. A Geological Section from Bessemer down Black River. [Geological Survey of Michigan, part of report for 1906, pp. 405–97. Lansing, 1907.]

—Hamberg, Axel. Die Eigenschaften der Schneedecke in den lappländischen Gebirgen. [Naturwissenschaftliche Untersuchungen des Sarekgebirges in Schwedisch-Lappland. Bd. I, Abt. III, Gletscherkunde, Lief. 1. Stockholm, 1907.]

—Harmer, F. W. The Origin of Certain Cañon-like Valleys. [Quarterly Journal Geological Society, Vol. XVIII, November, 1907.]

—Hayford, John F. The Earth a Failing Structure. [Philosophical Society of Washington Bulletin, Vol. XV, pp. 57–74. Washington, December, 1907.]

—Hill, Benj. F. and Udden, J. A. Geological Map of a Portion of West Texas, Showing Parts of Presidio, Brewster, Jeff. Davis, and El Paso Counties and South of the Southern Pacific Railway. [University of Texas Mineral Survey, Austin, 1904.]

—Hill, R. T. Geology of the Sierra Almoloya with Notes on the Tectonic History of the Mexican Plateau. [From Science, N. S., Vol. XXV, No. 644, pp. 710–12, map.]

—Hovey, Edmund Otis. The Foyer Collection of Meteorites. [American Museum of Natural History, Guide Leaflet No. 26, December, 1907. New York.]

—Hrdlička, Aleš. Skeletal Remains Suggesting or Attributed to Early Man in North America. [Smithsonian Institution, Bureau of American Ethnology, Bulletin 33. Washington, 1907.]

—Iowa Geological Survey, Volume XVII, Annual Report, 1906. [588 pp., 62 pls., 44 figs. Des Moines, 1907.]

—JAGGAR, T. A., JR. Journal of the Technology Expedition to the Aleutian Islands, 1907. [From the Technology Review, Vol. X, No. 1. 37 pp., 16 pls. Boston, 1908.]

—JENSEN, H. I. The Geology of the Warrumbungle Mountains. [From Proceedings of the Linnean Society of New South Wales, 1907, Vol. XXXII, Part 3, August 28.]

———. The Geology of the Nandewar Mountains. [Ibid., Vol. XXXII, Part 4, November 27.]

—JORDAN, D. S. and BRANNER, J. C. The Cretaceous Fishes of Cerará, Brazil. [From Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. LII, Part I, pp. 1–29, pls. I–VIII. Washington, April 29, 1908.]

—JORDAN, DAVID STARR, AND OTHERS. The California Earthquake of 1906. [San Francisco: A. M. Robertson, 1907. 360 pp., numerous illustrations.]

—KAYSER, EMANUEL. Lehrbuch der geologischen Formationskunde. Dritte Auflage. [Stuttgart. Verlag von Ferdinand Enke, 1908.]

—KEMP, JAMES FURMAN. Geology. [Columbia University Press. 35 pp. New York, 1908.]

—KEYES, CHARLES R. Genesis of the Lake Valley Silver Deposits. [Read before the American Institute of Mining Engineers, at the Toronto Meeting, July, 1907.]

—LANE, ALFRED C. Eighth Annual Report of the State Geologist to the Board of Geological Survey for the Year 1906. [Pp. 577–94. Lansing, 1907.]

—LEWIS, J. VOLNEY. Structure and Correlation of Newark Trap Rocks of New Jersey. [Bulletin of the Geological Society of America, Vol. XVIII, pp. 195–210, pls. 1–2. New York, May, 1907.]

———. Copper Deposits of the New Jersey Triassic. [From Economic Geology, Vol. II, No. 3, pp. 242–57, April–May, 1907.]

—LINGREN, WALDEMAR. The Production of Gold and Silver in 1906. [Advance chapter from Mineral Resources of the United States, 1906. U. S. Geological Survey, Washington, 1907.]

—MANSON, MARSDEN. An Attempt to Explain the Evidences of Glacial Action during the Permian. [Presented to the Centenary of the Geological Society of London, September, 1907.]

—MARGERIE, EMM. DE. La carte géologique internationale de l'Amérique du Nord. [Annales de Géographie, tome XVII, 1908.]

—MCCOURT, W. E. The Fire-Resisting Qualities of Some New Jersey Building-Stones. [From the Annual Report of the State Geologist of New Jersey for 1906. Trenton, 1907.]

—MERRILL, GEORGE P. The Meteor Crater of Canyon Diablo, Arizona; Its History, Origin, and Associated Meteoric Irons. [From Smithsonian Miscellaneous Collections, Vol. L, Part 4. Washington, 1908.]

—NORTH DAKOTA, Fourth Biennial Report of the State Geological Survey of. [324 pp., 37 pls., map. Bismarck, 1906.]

—OGILVIE, I. H. A Contribution to the Geology of Southern Maine. [From the Annals of the New York Academy of Sciences, Vol. XVII, Part II, No. 5, September 10, 1907.]

—PARR, S. W. AND HAMILTON, N. D. The Weathering of Coal. [University of Illinois, Bulletin No. 17. 36 pp. Urbana, 1907.]

—PEACH, HORNE, GUNN, CLOUGH, HINXMAN, AND TEALL. The Geological Structure of the North-west Highlands of Scotland. [Memoirs of the Geological Survey of Great Britain, 1907. 653 pp., 52 pls., 66 figs.]

—RANSOME, FREDERICK LESLIE. The Association of Alunite with Gold in the Goldfield District, Nevada. [From Economic Geology, Vol. II, No. 7, October–November, 1907.]

—REUDEMANN, RUDOLPH. The Graptolites of New York. [New York State Museum, Memoir 11. 557 pp., 31 pls., 482 figs. Albany, 1908.]

—RIES, HEINRICH. What Should Be Embraced in a Geological Study and Report on Clays? [Transactions of the American Ceramic Society, Vol. IX.]

———. Notes on the Rational Composition of Clays. [Transactions of the American Ceramic Society, Vol. IX.]

—ROMER. Atlas Geograficzny. [We Lwowie, 1908.]

—RUSSELL, ISRAEL C. The Surface Geology, of Portions of Menominee, Dickinson, and Iron Counties, Michigan. [Part of the report for 1906 of the Geological Survey of Michigan, pp. 5–82. Lansing, 1907.]

—SARGENT, C. S. Crataegus in Southern Michigan. [From Michigan Geological Survey, Report for 1906. Lansing, 1907.]

—SCHWARZ, E. H. L. The Andulusite Schist of George. Sapphire-Cyanite Rock from the Jagersfontein Mine. [Records of the Albany Museum, Vol. II, No. II, December 24, 1907.]

———. The Tygerberg Anticline. [From the Geological Magazine, N. S. Decade V, Vol. IV, November, 1907. 4 pp., 1 pl. London: Dulau and Co.]

—Science Yearbook, 1908. [London: King, Sell and Olding.]

—SEE, T. J. J. The New Theory of Earthquakes and Mountain Formation, as Illustrated by Processes Now at Work in the Depths of the Sea. [From Proceedings of the American Philosophical Society, Vol. XLVI, pp. 369–416, 1907.]

—SLOCUM, A. W. New Crinoids from the Chicago Area. [Field Columbian Museum, Geological Series, Vol. II, No. 10, pp. 273–306, pls. LXXXII–LXXXVII. Chicago, October 31, 1907.]

—SMITH, WARREN D. The Geology of the Compostela-Danao Coal Field. [From the Philippine Journal of Science, Vol. II, No. 6, pp. 377–403, pls. I–XV, maps 1–2. Manila, December, 1907.]

—Smithsonian Miscellaneous Collections, Quarterly Issues, Vol. IV, Parts 3 and 4. Washington, 1907, 1908.]

—SOLLAS, W. J. On the Cranial and Facial Characters of the Neanderthal Race. [Philosophical Transactions of the Royal Society of London. Series B, Vol. 199, pp. 281–339. London, 1907.]

—SPENCER, J. W. W. The Evolution of the Falls of Niagara. [Department of Mines, Geological Survey Branch. 470 pp., 43 pls., 30 figs., map. Ottawa, 1907.]

—STEINMANN, G. Ueber Gesteinsverknetungen. [Aus dem Neuen Jahrbuch für Mineralogie, Geologie, and Paläontologie. Stuttgart, 1907.]

—Terrestrial Magnetism, Department of, of the Carnegie Institution of Washington. Annual Report of the Director, 1907. [From Yearbook No. 6, pp. 154–66, pls. 10–11.]

—Transvaal Mines Department. Report of the Geological Survey for the Year 1906. [Pretoria, 1907.]

—WAHL, W. Analogien zwischen Gliedern der Pyroxen und Feldspat-Gruppen und über die Perthitstrukturen. [Oefversigt af Finska Vetenskaps-Societetens Fördhandlingar. L 1906–07. N:02. Helsingfors, 1908.]

———. Ueber einen Magnesiumdiopsid führenden Diabas von Källsholm, Skärgard von Föglö, Ålandsinseln. [Aus der Festschrift zum siebzigsten Geburtstage von Harry Rosenbusch gewidm. von seinem Schülern. E Schweitzerbartsche Verlagsbuchhandlung, Stuttgart, 1906.]

—WALCOTT, CHARLES D. Cambrian Geology and Paleontology. No. I.—Nomenclature of Some Cambrian Cordilleran Formations. No. II.—Cambrian Trilobites. [Smithsonian Miscellaneous Collections, part of Vol. LIII. Washington, 1908.]

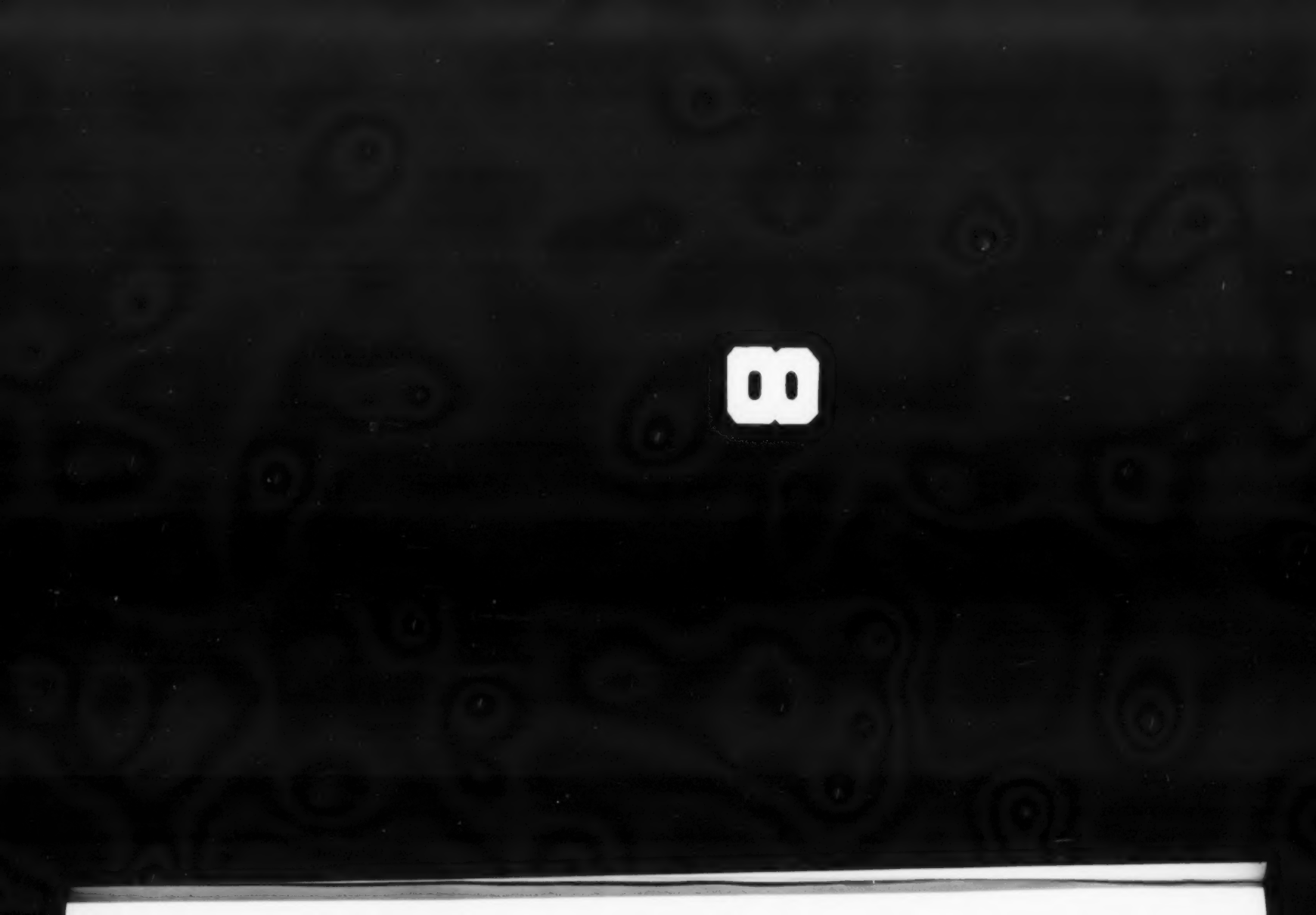
—Washington Academy of Sciences, Contents, Organization and Membership of the, and Index. [Proceedings of the Washington Academy of Sciences, Vol. IX, 1907, pp. 523–58. Washington, 1908.]

—WILLIAMS, HENRY S. The Dalmanellas of the Chemung Formation, and a Closely Related New Brachiopod Genus, Thiemella. [From Proceedings of the United States National Museum, Vol. XXXIV, pp. 35–64, pls. II–IV. Washington, 1908.]

—WILLISTON, S. W. What Is a Species? [From The American Naturalist, Vol. XLII, No. 495, March, 1908.]

—YABE, H. On the Occurrence of the Genus Gigantopteris in Korea. [Journal of the College of Science, Imperial University, Tokyo, Japan. Vol. XXIII, Art. 9.]

—YOKOYAMA, M. Palaeozoic Plants from China. [Journal of the College of Science, Imperial University, Tokyo, Japan. Vol. XXIII, art. 8.]



JAMES HALL
STATE GEOLOGIST OF NEW YORK
1837 – 1898
ESTABLISHED IN THIS
FOURTH GEOLOGICAL DISTRICT
THE CLASSIFICATION OF A LARGE PART OF THE
NEW YORK SYSTEM OF GEOLOGICAL FORMATIONS
WHICH GAVE ENDURING REPUTE TO THE GEOLOGY OF NEW YORK
THIS GORGE EXHIBITS THE TYPICAL EXPRESSION OF HALL'S
PORTAGE GROUP
WHOSE ROCKS CARRY AN ASSEMBLAGE OF ORGANIC
REMAINS MOST WIDELY DIFFUSED THROUGHOUT THE WORLD
THIS TABLET HAS BEEN ERECTED BY
CHARLES D WALCOTT SECY SMITHSONIAN INSTITUTION
JOHN J STEVENSON PROF GEOLOGY NY UNIVERSITY
JOHN C SMOCK COMMISSIONER GEOLOGICAL SURVEY OF NEW JERSEY
CHARLES SCHUCHERT PROF GEOLOGY YALE UNIVERSITY
JOHN M CLARKE NY STATE GEOLOGIST
1903